

# THE TEACHING OF SCIENCE IN SECONDARY SCHOOLS

*Compiled by a Joint Committee of the  
Incorporated Association of Assistant Masters and the  
Science Masters' Association*



LONDON  
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## FOREWORD

Over a period of many years the Incorporated Association of Assistant Masters in Secondary Schools has repeatedly drawn on the experience of its members and friends in order to compile memoranda on the teaching of the main subjects in the secondary school curriculum. The need for a memorandum on the teaching of science has long been recognised and it is hoped that this need will be met by the present publication, the work of a joint committee of the Science Masters' Association and the Incorporated Association of Assistant Masters.

This book will probably be of special value to teachers in schools which provide a "grammar school type of education," but it should be of interest and help to all teachers of science subjects. In expressing the hope that "The Teaching of Science in Secondary Schools" will have a wide circulation and an important influence on the theory and practice of science teaching in all schools, the Executive Committee desires to place on record its sincere appreciation of the devotion, energy, and knowledge of all those whose co-operation has made possible the completion of this work.

A. W. S. HURCHINGS.

Secretary, Incorporated Association of  
Assistant Masters in Secondary Schools.





## PREFACE

Early in 1935, largely owing to the initiative of the late Mr. W. H. Jenkinson and of Mr. F. W. G. Ridgewell, the Education Sub-Committee of the I.A.A.M. discussed the need for the compilation of this book. It was decided that the knowledge and experience of science masters should be made available to all and particularly to new entrants to the profession. In that year a joint committee of the Incorporated Association of Assistant Masters in Secondary Schools and the Science Masters' Association was set up ; it consisted of 12 I.A.A.M. members and 8 from the S.M.A.; actually most of the 20 were members of both associations. In September 1935, the first meeting was held under the Chairmanship of Mr. W. H. Jenkinson, Messrs. Ridgewell and Lauwerys being the Honorary Secretaries. It was realised that the task upon which the committee had embarked was a gigantic undertaking, but by means of questionnaires and correspondence about 200 corresponding members were drawn into the work, which progressed steadily till 1938. During that time the committee suffered grievous losses in the deaths of the Chairman and of Mr. W. R. Anderson. Mr. S. V. Brown, himself never to see the fruits of his labours, succeeded Mr. Jenkinson as Chairman and Mr. S. R. Humby became Vice-Chairman. In 1938 an Editing Committee was set up, Mr. S. R. Humby and Dr. E. J. F. James doing the final editing for publication. In 1939 everything was ready, including arrangements with the publishers. War broke out, and it was decided to defer publication until after the war.

During the early war years the work was in abeyance, but in 1944 a new Joint Committee was formed, with Mr. S. V. Brown as Chairman, and its immediate task was the revision and publication of the Science Memorandum, as it was then called. Again the Committee lost its Chairman by death ; Mr. S. R. Humby succeeded Mr. S. V. Brown and has brought the book to its final form.

The greater part of the work is unchanged and most of it is the work of the original committee. Though every member contri-

buted his quota, probably all will agree that Messrs. Humby and Ridgewell should be singled out for particular mention for the many hours of painstaking, though tedious, work they have undertaken.

To all members of the Committee, whose names are appended, the thanks of both associations are due :—

- \* W. R. Anderson, late of St. Dunstan's College, Catford.
- ¶ W. Ashhurst, Epsom College.
- \* L. F. H. Audcent, formerly of Fairfield Secondary School, Bristol.
- \* H. J. Bonham, formerly of Crypt Grammar School, Gloucester.
- \* J. Howard Brown, Lord Williams's Grammar School, Thame.
- \*†¶ S. V. Brown, Vice-Chairman and later Chairman, late of Liverpool Institute High School for Boys.
- † W. G. Davies, Royal Grammar School, Newcastle-on-Tyne.
- ¶ R. H. Dyball, City of London School.
- \* C. A. W. Fentiman, King Edward's Grammar School, Camp Hill, Birmingham.
- ¶ G. Fowles, Latymer Upper School, W.6.
- \*¶ A. P. Graham, King Edward VII School, Sheffield.
- ¶ J. Harris, St. Dunstan's College, Catford.
- ††¶ S. R. Humby, Winchester College, Vice-Chairman and later Chairman.
- † J. Clay Jenkins, Christ's College, Finchley.
- \* W. H. Jenkinson, Chairman, late of Central Grammar School, Sheffield.
- \*† J. A. Lauwerys, Minuting Secretary, Institute of Education.
- ¶ D. H. J. Marchant, County High School for Boys, Barkingside.
- \* H. S. Moodey, formerly of Hampton Grammar School.
- \* L. Oulton, Abertillery County School.
- \* W. J. Ray, Lawrence Sheriff School, Rugby.
- \* A. I. Rees, formerly of Cathays High School, Cardiff.
- \*†¶ F. W. G. Ridgewell, Corresponding Secretary and Secretary of Post-War Revising Committee, Beckenham and Penge County Grammar School.
- \* E. M. Rogers, formerly of Charterhouse School.
- \* E. Scott, formerly of Itchen Grammar School.
- † L. F. R. Simmonds, formerly of Sir George Monoux School, Walthamstow.
- \* L. G. Smith, Trowbridge High School for Boys.

- ¶ A. W. Wellings, formerly of Leamington College for Boys.
- \* C. A. E. Whish, late of Ashton-in-Makerfield Grammar School.
- ¶ L. W. White, Tiverton Grammar School.
- \* W. B. Yapp, formerly of Manchester Grammar School.
- \* Member of original Committee.
- † Member joining Committee later.
- ‡ Member of original Editing Sub-Committee.
- ¶ Member of Post-War Revising Committee.

Sincere thanks are due also to some 200 corresponding members in schools of various types and sizes in all parts of the country. It is regretted that paper supplies do not allow of the inclusion of a full list of names.

Acknowledgements and thanks are tendered to the following, without whose help the work could not have been completed :—

(1) A number of experts who have been consulted by the Equipment Sub-Committee on technical matters. These include members of the Royal Institute of British Architects (Messrs. G. Fairweather, T. E. Scott, and H. Ingram Ashworth), who considered various aspects of the report and made numerous suggestions which have been incorporated : Members of the Staff of the Forest Products Research Laboratory, Princes Risborough (Messrs. C. J. Chaplin, W. G. Campbell, and H. A. Cox), who supplied valuable information on laboratory timbers : Mr. W. Somerville Vernon of the Technical College, Cardiff, who wrote the section on Home-Made Apparatus : The British Electrical Development Association : The British Waterworks Association : The Cardiff Gas, Light, and Coke Company : Messrs. Ernest Griffiths and Sons, Consulting Engineers, Liverpool. The number of science masters who have sent information and suggestions is so great as to make it impossible to acknowledge them individually. To the science staffs of the following—among many others—the Equipment Sub-Committee feels especially indebted: Almondbury, Ashton-in-Makerfield, Bolton, Dover County, Fowey, Guildford, Hull Grammar, Keighley, West Leeds High, Wyggeston, Loughborough, Marlborough College, Neath, Okehampton, Penarth, St. Edward's Oxford, Stratford-on-Avon, Upholland, West Bromwich.

(2) The Legal Sub-Committee of the I.A.A.M., who drew up the chapter on the legal responsibilities of science masters.

(3) The Ministry of Education for permission to publish Administrative Memorandum No. 167.

(4) The eight Examining Bodies who kindly made available the statistics used in Chapter VII.

(5) Dr. E. J. F. James, High Master of Manchester Grammar School, formerly of Winchester College, who gave so much time in assisting Mr. S. R. Humby in the pre-war final editing.

(6) Dr. A. W. Panton, of West Wickham, Kent, who kindly read through Chapter XI and assisted considerably with suggestions and advice.

(7) The Scientific Film Association, whose Education Committee assisted with Chapter VIII.

(8) Mr. D. H. J. Marchant of the County High School for Boys, Barkingside, Essex, who prepared the Index.

Speaking as a non-member of the Committee, I express my opinion that the Committee has done its job thoroughly and well, and that many science masters will find in this book advice that will help them to overcome most of the difficulties which arise in the school laboratory and in the science lecture room. For this reason a copy of this book should be found in every staff library and in the libraries of University Training Departments.

Without necessarily being an expression of I.A.A.M. policy on every point, the book can fairly be said to reflect truly the opinions of science members of the I.A.A.M. If it fulfils its purpose of improving the science teaching and science facilities in our schools, I am sure that the members of the Committee will feel that their labours have not been in vain.

C. J. COZENS,  
Chairman of the I.A.A.M., 1947.

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## CHAPTER I

### A SHORT HISTORY OF SCIENCE TEACHING

The claims for the introduction of science into the curriculum of secondary schools were first recognised during the nineteenth century.

The realisation by the general public of the need for Natural Science to be taught in schools was due to the great advances in science made during this period, and to the writings of such men as Faraday, Spencer, and T. H. Huxley, all of whom urged both the utilitarian and disciplinary values of science teaching.

At the end of the eighteenth century the universities sadly neglected the natural sciences and the chief scientific discoveries were made by amateurs, such as Cavendish, Priestley, James Watt, and Herschel. As a sign of a fairly widespread dissatisfaction with the gap between educational provision and social needs, there arose a large number of scientific and philosophical societies, such as the Society of Arts of London, founded in 1754 for the "encouragement of the arts, manufactures, and commerce of the country;" the Literary and Philosophical Society of Manchester, founded in 1781, and numbering Dalton and later Joule among its members; and the Lunar Society of Birmingham, founded in 1766 by Erasmus Darwin, and having as prominent members Priestley, Watt, Josiah Wedgwood, and Herschel.

In 1799 Rumford was influential in founding the Royal Institution of Great Britain. At first it was intended that the Institution should be a centre for teaching young men in the mechanical professions by "courses of philosophical lectures and experiments on the applications of science to the common purposes of life," but under the influence of Sir Humphry Davy and of Faraday, its policy became completely changed. These two possessed powers of research and lucid exposition to such an extent that society crowded to hear their lectures and be told of their discoveries.

Faraday was indefatigable in giving lectures at the Royal

Institution ; there he started in 1826 the famous Friday evening discourses, and in the following year, the Christmas lectures " adapted to a juvenile auditory."

An important movement to teach science commenced with the mechanics' institutes of the early nineteenth century. One of the earliest recorded attempts to teach what may be termed " popular science " was that of John Anderson, who gave a course of lectures on Experimental Physics to an invited audience, most of whom were tradesmen or mechanics, at Glasgow in or about the year 1760.

Anderson was convinced of the cultural possibilities of science teaching and bequeathed his property to found a university in which science should hold the chief place. The sum his estate realised on his death, however, was not large, and it was therefore devoted to the founding of a Professorship of Physics at Glasgow University. The first occupant of this chair was George Birkbeck, who was an enthusiastic lecturer and had a quantity of demonstration apparatus made under his own supervision in the workshops of the town. So much interest was shown by the artisans in this work that Birkbeck invited the men to attend his lectures, but as a great many availed themselves of his offer, he was obliged to form separate classes in a building which became known as Anderson's Institution.

Birkbeck left Glasgow in 1804 to take up a medical practice in London, but similar courses were continued year after year, and led eventually to the formation in 1823 of the Glasgow Mechanics' Institute. In the same year the London Mechanics' Institute was established ; since then its original name has been twice changed ; first, in 1866 to the Birkbeck Literary and Scientific Institution, and secondly, in 1907 to Birkbeck College. As a school of the University of London, Birkbeck College still provides university training in the evenings for those who earn their living by day.

In 1886 the Mechanics' Institute at Glasgow became the Glasgow Technical College ; many other provincial technical colleges had similar beginnings. The Liverpool Mechanics' Institute, founded in 1825, ultimately became an independent secondary school until 1902 when the Balfour Act placed the onus of providing secondary education on the Local Authorities. The governors of the school thereupon handed over the institution, together with considerable endowments, to the City Educa-



tion Authority, stipulating only a measure of autonomy with regard to the constitution of the Governing Body. Thus the Liverpool Institute, as it is now called, claims to be the first secondary school under the control of a local authority. The Mechanics' Institute was established in Birmingham in 1825 and survived until 1848, when it was revived in a new form as the Polytechnic Institute, which became the Birmingham and Midland Institute in 1853.

During the whole of the nineteenth century institutions similar to these were becoming more and more numerous and were attracting large numbers of artisans and mechanics anxious to obtain instruction in the arts and sciences, particularly those connected with their occupations in factory and workshop.

In the early part of the nineteenth century many other forces were at work for the spread of education; more and more philosophical societies came into existence and various societies for the education of the poor were founded. Amongst the latter the more important were the National Society, founded in 1811, and the British and Foreign Schools Society, established in 1814. With the help of a large number of supporters these two societies managed to establish schools in nearly every village in the country.

By the middle of the nineteenth century, however, there were very few schools giving any form of instruction in science. Only the public and grammar schools were in a position to do so, for such other schools as then existed had facilities for nothing but the most rudimentary forms of instruction, and had difficulty in retaining their pupils long enough to teach them to read and write with any facility.

Most of our knowledge of the state of science teaching in schools during the last century is to be found in the Reports of the various Royal Commissions on Education which sat almost continuously from 1861 onwards. The first of these was the Public Schools Commission, which was appointed by the Government to inquire into the administration of nine great public schools,\* and sat from 1861 to 1864. The Commissioners were of opinion that the course of study provided in these schools was sound in its main elements, Latin and Greek, but was lacking in breadth and flexibility. In all nine schools Arithmetic and

\* Eton, Winchester, Westminster, Charterhouse, St. Paul's, Merchant Taylors', Harrow, Rugby, and Shrewsbury.

Mathematics were taught. At Rugby, Natural Science was taught to boys who elected to study it instead of languages, and lectures on this subject were given at Winchester and occasionally at Eton.

The Commissioners pointed out in their Report that Natural Science was thus practically excluded from the education of the upper classes in England ; a state of affairs which revealed " a plain defect and a great practical evil." They therefore urged that Natural Science should be taught where practicable and should include two main branches, one comprising Physics and Chemistry, and the other Comparative Physiology and Natural History.

At the time of this enquiry there is no doubt that science teaching was already firmly established at Rugby and was conducted on much sounder lines than in other institutions where the subject was taught by lectures or private study. Under Dr. Arnold, Physics had become a subject of instruction in 1837, but Dr. Tait, his successor as headmaster, introduced Botany, Chemistry, and Geology into the curriculum and in 1859 a science lecture room and laboratory were built at a cost of over £1,000. Rugby was thus the first large school to include science in its curriculum.

The increase in wealth of the middle classes during the nineteenth century led to the establishment of new boarding schools. Most of these schools developed early in their existence modern sides designed to prepare boys for one of the Services or for commercial careers. To this end Mathematics became a main study, Natural Science was introduced, and more stress was laid on modern languages.

The curriculum introduced into Uppingham by Edward Thring, headmaster from 1853 to 1887, is of interest as it included several optional subjects. The traditional subjects were taken in the morning and in the afternoon came the optional subjects, including Chemistry ; of these every boy had to take one or two. Thring attached great importance to hobbies and it was largely due to the indirect influence of his methods that out-of-school activities such as Natural History Societies were started in schools after 1868.

The claims for science teaching were further stressed by the Great Exhibition of 1851, when much was heard about the relative superiority of continental technicians over our own. The insistent demands that were made at this time for the

introduction of Natural Science into the curriculum of our schools resulted in the establishment in 1853 of the Department of Science and Art for the "encouragement of science and art."

In 1854 three eminent scientists urged the claims of science as an essential part of general education. T. H. Huxley delivered an important address on the Educational Value of the Natural History Sciences; John Tyndall lectured on the Importance of the Study of Physics as a Branch of Education; Faraday stressed the importance of cultivating the scientific outlook in a lecture on the Education of the Judgment.

In 1861 Herbert Spencer, who believed that a knowledge of life was the most important knowledge of all, published four essays under the title of "Education: Intellectual, Moral, and Physical." The most prominent advocate, however, of the teaching of Natural Science in the 'sixties and 'seventies was Huxley, who persistently urged that science should be included in any adequate scheme of secondary education.

It was at this time that Huxley's famous *Physiography* became the standard text-book for science students and a very fine book it was: it gave unity to science for the first time. It is interesting to note how the present tendency towards General Science has resulted in demands for a text-book "something like Huxley's *Physiography*."

Canon J. M. Wilson, at that time a science master at Rugby, in an essay on "Science Teaching" published in 1867 in a volume entitled *Essays on a Liberal Education*, expressed his view that a study of two unlike branches of Natural Science was a necessary part of any complete education, and emphasised the habits of accurate observation, exact reasoning, and power to judge evidence, which could be developed by good scientific teaching. At Clifton, where he was headmaster from 1879 to 1890, Canon Wilson was able to put his ideas into practice and did much to encourage the teaching of science.

The establishment of the Natural Sciences Tripos at Cambridge in 1851, and of the Honours School of Natural Science at Oxford in 1853, undoubtedly helped further to prepare the way for the inclusion of science in the curriculum of secondary schools.

In 1864 another Royal Commission was appointed to enquire into the education given in secondary schools as a whole. The Report of this Commission, which is usually known as the Schools Inquiry Commission, was published in 1868. It shows that very

few schools had introduced science and, of those that had, only eighteen devoted as much as four hours a week to the subject. The Commissioners pleaded that science teaching could best be made a valuable discipline if it began with sciences that appealed principally to the faculties of simple observation, such as Botany, and ended with Physics and Chemistry as the basis of all the sciences.

A full survey of the position of science teaching in secondary schools towards the end of the nineteenth century was contained in the Sixth Report of the Royal Commission on Scientific Instruction and the Advancement of Science, published in 1875. This is usually referred to as the Devonshire Commission. The Report begins with a full discussion of the difficulties attending the introduction of science teaching into schools and goes on to recommend that (i) in all public and endowed schools a substantial portion of the time allotted to study should, throughout the school course, be devoted to Natural Science, and that not less than six hours a week on the average should be assigned to this purpose ; (ii) school laboratories should be constructed to supply accommodation for practical work in Physics as well as in Chemistry.

Although the expense involved in the building of school laboratories and increasing the staff deterred many governing bodies from taking immediate steps towards encouraging the teaching of science, headmasters began to realise that science had come to stay. The publication of this Report marked the beginning of the widespread introduction of Physics and Chemistry into the curriculum of boys' schools and of Botany into that of girls' schools.

As the Natural Sciences had only just attained an acknowledged position in the older universities, such qualified teachers as were immediately available had taken either the examinations of the Science and Art Department or those of the University of London.\*

Public examinations in science as well as in other subjects are of comparatively recent origin. In 1852 the Society of Arts of London formed a union of the mechanics' institutes and held science examinations designed to qualify for membership. At first the efforts of the society in this direction met with little

\* At London the Faculty of Science was created, and degrees in Science were first conferred in 1860, but the teaching of Natural Science in the university was well established before this date.

response, but in the course of a few years the system became established and papers were set in Chemistry, Physiology, Botany, Mathematics, and Mechanics. These early examinations were intended for students who had left school and who were at least fifteen years of age; as a guide for the candidates the society published a handbook entitled *How to Learn and What to Learn*.

The action of the Society of Arts awakened the interest of the older universities and so led to the organisation of local examinations by both Oxford and Cambridge. These examinations, instituted in 1857-58, were intended to meet the needs of what were then called "middle class" schools.\* On the recommendation of the Schools Inquiry Commission of 1868, the endowed schools also availed themselves of the advantages offered by such external tests. In 1873 the Oxford and Cambridge Schools Examination Board, or "Joint Board" was established for the purpose of examining those schools which sent a large number of pupils to the older universities.

The Science and Art Department at South Kensington gave grants to certain schools in which science was taught and where the older pupils were presented for the examinations of the department. Such schools had been founded after 1870 by School Boards in the large urban areas where it had been found necessary to provide accommodation for the increasing number of pupils who remained at school beyond the age of thirteen and for pupil teachers between sixteen and eighteen years of age. The schools which were selected for this purpose had an upper portion arranged as an Organised Science School (or Course); the same arrangement held in many private and grammar schools which had been tempted by the generous grants of the Science and Art Department to adopt the same curriculum.

The teaching of science in these Organised Science Schools made the pupils familiar with the ground covered by voluminous text-books, but was mainly devoted towards the acquisition of knowledge which could be readily reproduced in examination answers. It is from this time onwards that science teaching in boys' schools was concerned with Physics and Chemistry and almost entirely neglected Biology.

\* These were private boarding or day schools founded by the National Society after 1838 and were designed to serve the needs of the middle and lower classes. After 1869 many middle class schools were merged with ancient grammar schools by the Endowed Schools Commission (1869-1874), and by the Charity Commission (1874-1902).

By the Education Act of 1899 the powers of the Department of Science and Art and of the Education Department were merged in the new Board of Education. The Organised Science Schools were then discouraged and new secondary schools were compelled to take as their model the curriculum of the existing public and grammar schools.

The outstanding personality in the teaching of science during the late 'eighties and early 'nineties was H. E. Armstrong, Professor of Chemistry in the Central Technical College, City and Guilds of London Institute. Professor Armstrong became profoundly dissatisfied with the science work of the schools and was severely critical of the teaching methods then adopted. He advocated that all pupils, even beginners, should be allowed to discover things for themselves, and should be put in the position of an original observer.\*

This particular method of teaching, which became known as the heuristic method, was first used at St. Dunstan's College, of which Professor Armstrong was a governor. It has now been largely modified since it was found that mainly through lack of time, practice simply could not follow precept. Nevertheless, the heuristic spirit still permeates the whole of science teaching. There is no doubt that for nearly half a century Professor Armstrong's criticisms kept science masters from becoming too complacent of their own teaching methods (see pp. 132 and 143).

Since the beginning of the present century there has been a continuous increase in the facilities and equipment for teaching science in schools, and claims have been successfully pressed for the inclusion in the curriculum of General Science (which includes some Biology) and of Biology itself.†

The Great War of 1914-18 opened the eyes of the general public to the importance of science in the world of to-day. In 1916 the Prime Minister appointed a committee, under the chairmanship of Sir J. J. Thomson, to inquire into the position occupied by Natural Science in the educational system of Great Britain, especially in secondary schools and universities. Its conclusions and suggestions, commonly called the "Thomson Report," were published in 1918 under the title, *Natural Science in*

\* Professor Armstrong's views on education are expressed in the papers which he collected in *The Teaching of Scientific Method* (Macmillan, 2nd edition, 1910).

† The history of the General Science Movement is admirably summarised in the Interim Report of the sub-committee of the S.M.A. appointed to consider the teaching of General Science (John Murray, 1936).

*Education.* Many of the best recommendations still remain as suggestions. Nevertheless the report was fruitful in consequences: the Higher Schools Certificate was established, advanced courses in science were added to many schools, the Science Masters' Association and the Association of Women Science Teachers were formed, and helpful textbooks, inspired by the recommendations of the report, began to appear.

By meetings, discussions, the drawing up of model syllabuses, and the criticism of examination questions, the Science Masters' Association has done much to promote the welfare of school science. Of its many publications the noteworthy *General Science in Education*, Part I, appeared in 1936, and Part II in 1938.

The *School Science Review*, the S.M.A. periodical, has from small beginnings become an influential journal. Its articles by experienced members on their methods of teaching, its descriptions of new apparatus and experiments, its reviews of books, its answering of queries and discussion of difficulties combine to make it a great factor for the improvement of science teaching.

In 1933 the Board of Education set up a consultative committee on secondary education under the chairmanship of Sir Will Spens. Its conclusions and recommendations—commonly known as the "Spens Report"—were published in 1938. Teachers were disappointed with the attitude of the Report towards school science and both the I.A.A.M. and S.M.A. published severe criticisms of the recommendations.

A few years later, in view of impending changes in our educational system, the Board of Education considered that the curriculum and examinations in secondary schools should once more be subject to review. The task was entrusted to a Committee of the Secondary Schools Examination Council under the Chairmanship of Sir Cyril Norwood. Their conclusions, published in 1943, and briefly known as the "Norwood Report," contain a chapter dealing with the teaching of school science.

In April 1945 the new Education Act of 1944 came into force. It proposes the raising of the school age, the extension of secondary and technical education, and the conversion of the Board of Education into a Ministry. It is too early to discuss the possible effect of this Act on school science, for at the time of writing there is available neither the school accommodation nor a sufficient number of qualified teachers to carry out its requirements.

## CHAPTER II

### THE AIMS AND FUNCTIONS OF SCIENCE TEACHING

#### *The Aims of Science*

Science seeks knowledge and understanding of the world and of life itself by a method which consists essentially of careful observation and classification of phenomena, of experiment, and of the formulation of so-called laws which summarise our knowledge of groups of observed facts.

These laws are accepted only in so far as they are able to include all observed results. They are subjected continuously to re-examination and testing by further experiment. They are valued if they lead to further discoveries.

Science thus demands freedom from bias and the ability and determination to judge facts objectively. The scientist must be trained to estimate the value of evidence, to suspend judgment in the face of incomplete information, and to subordinate personal prejudices to the acceptance of facts revealed by careful observation and wisely devised experiments.

Scientific studies show how the resources of nature can be used for the benefit of man and, while some scientists work solely to extend the boundaries of knowledge, others are endeavouring to adapt that knowledge to man's service. The discoveries made have been placed freely at the disposal of all and the debt which the community owes to science should be known to every citizen.

#### *The Aims of Science Teaching in Schools*

The teaching of any subject at school is usually justified or defended for cultural, disciplinary, and utilitarian reasons. Science can justify its inclusion in the curriculum on each of these grounds. Science teaching in a school has a twofold function to perform. It must give the student a systematic training in careful observation, in experiment, and in the estimation of the relative value of results. It must provide, for all, a knowledge of the material world and of the forces of nature.



At the same time, for the small proportion of pupils who will later become scientists, it must lay a sound foundation for more advanced work.

Considered as a mental discipline, science requires exact and accurate observation, care and thoroughness of technique, the logical interpretation of data and the intelligent estimation of the reliability of results. The transfer of such desirable qualities to the general outlook of students should be a conscious aim of the teacher.

Science has equally important contributions to make to the cultural development of the pupils. An intelligent understanding of human society is incompatible with ignorance of science since the characteristic features of modern civilisation depend on man's conquest of nature by the application of scientific knowledge. School science teaching will attempt to give pupils a knowledge of the outstanding discoveries on which our civilisation has been built up and an appreciation of the relation of these facts to other influences which have affected man's development. It may make them desirous of contributing their share to the advance of mankind. For this purpose they must have a broad knowledge of many scientific principles and facts; though that knowledge may not be profound, it must be scientific and not merely encyclopædic.

A knowledge of science has obvious utilitarian value not only to the minority who will use their knowledge in their work but to all in their everyday life. The schools must therefore aim at showing how scientific principles can be applied to common problems, for instance in the home or in the garden. Many children get much pleasure from hobbies and interests of a scientific type; school science teaching should encourage such interests so that they lead to a wise use of leisure and to the enjoyment of beauty in nature. /

### *The Scope of Science Teaching.*

The content of a science course should vary according to circumstances and it is therefore intended to suggest a wide variety of possible topics from which a suitable course can be chosen, rather than to lay down an irreducible minimum. It is a great mistake to leave pupils with the impression that science consists of Chemistry and Physics only, or worse still of Chemistry and some branches of Physics, such as Heat and Light. It is

strongly urged that Biology should be included and that in the pre-School Certificate stage at least one-quarter of the time available for science should be given to biological work.

This does not imply any hard-and-fast line of division between the various branches of science, but it is recognised that Physics and Chemistry will always require a large share of the science time because they are required in studying other branches of science and also because they lend themselves particularly well to experimental treatment under the conditions obtaining in schools. As Mechanics is the basis of considerable parts of Physics, it should not be neglected. In the earlier part of the course there should be much out-of-door observational work—"nature study" in its widest sense.

This "General Science" approach to the study of science is still in the experimental stage. It is clear, however, that if one aims at covering a definite course its content must be considerably smaller than the total of the School Certificate requirements in Chemistry, Physics, and Biology to-day. This curtailment may be made as some of the present requirements are of little lasting value to those who do not continue their scientific studies after leaving school. It is better to choose a less crowded course from a more extended field.

Examinations need not make it impossible to have a diversity of syllabus from school to school and even from class to class. Modifications of some examinations may be necessary. Thus there might be (*a*) an extension of the practice of allowing schools to present their own syllabuses for approval, or (*b*) a wide choice of questions to cover several syllabuses.

A certain number of essential topics will probably have to be laid down, but the smaller this list is, the better. The last thing to be encouraged is the slavish following of a stereotyped course, however excellent it may appear; any examination which demands such a course must be reorganised. The teacher's choice of topics must be adjusted to circumstances—the interests of the children, the environment and resources of the school and especially his own particular abilities, interests, and enthusiasms, for on these the vitality of the course and its ultimate value will very largely depend.

In what has been said so far, it has been assumed that General Science will be taught. It must, however, be recognised that either from choice, or from force of circumstances, some schools

will continue the alternative approach through the teaching of separate science subjects for some time. There will therefore be three types of courses co-existing in the schools :—

- (1) where General Science is taken up to the School Certificate stage,
- (2) where two or three years of General Science are followed by one or two years of formal study of separate sciences, and
- (3) where the separate sciences are studied throughout the course.

It is suggested that where suitable staff and conditions are available, the first type of course is best for those pupils who will not continue the study of science beyond the age of sixteen. As regards (2), it is felt that such a course is satisfactory where at least two full science subjects are studied in the last one or two years, and not otherwise. The third type of course is common, but has grave disadvantages. Even if three full science subjects are taken, there is great difficulty in obtaining that unity of outlook that is now recognised as fundamental to a good science course. If, however, this difficulty can be overcome, there appears to be no reason why this type of course should not continue, as indeed it must do for some time if only because of the shortage of teachers able to teach both Physical and Biological Science. It must be recognised that an older teacher knowing no Biology may do much less good in trying to teach General Science than in teaching his own subject.

The claims of Geology to a place in the school science course have been pressed from time to time. It is felt, however, that though the subject may have particular value in a few special districts, it is not suitable as a full subject in the pre-School Certificate stage. Many geological topics already find a place in up-to-date courses on Geography and some should be included in a school course of General Science.

#### *The Present Position.*

It is regretted that the ideals which should inspire the teaching of science are too frequently rendered unrealisable by the fact that teachers are forced, either indirectly or directly, by the emphasis laid on examination results, to lay aside their ideals and to work for such results. The type of examination imposed often prevents a broad treatment of the subject and tends to reduce

science teaching to the memorising of facts and their reproduction as examination answers. This position can only be improved by a determined and combined effort by all parties concerned—teachers, examiners, education authorities, and parents.

*The Place of Science in the Curriculum.*

The aims of science teaching can only be properly fulfilled if science is allotted an appropriate place in the curriculum of every pupil. This claim has already been recognised in many schools, but the recognition is by no means complete. The practice in some schools of introducing a comparatively high degree of specialisation before the School Certificate is strongly deprecated. Whilst some choice of subjects may be dictated by examination requirements in the last year of the School Certificate course, it is felt that separation into Classical, Modern, and Scientific sides at this stage is premature and thoroughly undesirable.

The number of teaching periods per week which should be devoted to science must depend to some extent on the length of the course for the School Certificate, and also on the number of subjects taken. At the present time, in those schools where the age at entrance is from 10 plus to 11 plus, the course for School Certificate is usually four or five years in length, and there are indications that the five-year course is becoming more common.

There are a few cases where the course is only of three years' duration.

In the schools where pupils normally enter at 13 plus, the course for School Certificate often lasts only two or three years. The Council of the I.A.A.M. recently reaffirmed its opinion that in schools with the lower age of entry the School Certificate should normally be taken after a five-years' course at the age of 16, and it is with this policy in mind that the following suggestions are made. It must be remembered that whether the age be 10, 11, or 13 at entrance, the majority of the pupils have very little scientific knowledge or training.

It is considered that the absolute *minimum* of time which should be allotted to science in the ordinary secondary school is two hours per week (i.e. three teaching periods) between the ages of 10 and 12, and  $4\frac{1}{2}$  hours (six or seven teaching periods) per week between the ages of 12 plus and 16 plus. These allowances of time were recommended by Sir J. J. Thomson's Committee on "Natural Science in Education" as long ago as 1918, and

subsequent experience has shown the desirability of the demand. It cannot be emphasised too strongly that in many instances the apparent failure of science teaching is due to the neglect of this recommendation by headmasters and education authorities.

Where separate science subjects are studied the minimum satisfactory time allotment per subject is three periods per week per subject in the earlier years, followed by four periods per week in the School Certificate year.

In schools where the age at entrance is 13 plus and courses are usually shorter, it is even more imperative that this minimum time allowance should never be withheld and a more generous allocation of time should be made wherever possible. It may be urged that even the minimum time cannot be afforded, but it is submitted that it can be allowed if undue specialisation is avoided. Two-year courses are usually determined by the requirements of future University Scholarship Examinations. It is felt most strongly that it is fundamentally wrong that the general education given by the School Certificate course should be cramped by future specialist requirements. Two-year courses should be abolished if they cannot provide a good general education, including an adequate study of science.

## CHAPTER III

### LABORATORIES AND OTHER SCIENCE ROOMS

#### PLANNING

Laboratory planning is a matter of compromise. It is unwise to lay down hard-and-fast rules, for the advantages of flexibility must always be borne in mind. In the ideal case the internal arrangements of science rooms would be designed first, and the walls subsequently arranged to suit them. Because this process is almost invariably reversed, and also because the men who will have to work in the laboratories are seldom consulted before plans are drawn, few really satisfactory science blocks exist. An interesting one has been built at Marlborough College, where the Chemistry and Biology Laboratories are arranged in the form of the legs of an X, with the preparation rooms in the centre. The building is a *separate block*, and there is no doubt that most science masters prefer this arrangement, which undoubtedly facilitates planning. Failing this, much may be done when the science rooms are at the end of a block.

Science masters and architects must work hand in hand if a satisfactory lay-out is to be secured. In this way the best co-ordination of rooms and services will be obtained. Education Authorities differ greatly in the extent to which they utilise a science master's knowledge and experience. It is sufficient to quote two examples of procedure recently adopted.

In one case a County Authority submitted to the headmaster concerned a plan of the whole building. Laboratories were shown in outline only and were in accordance with the Ministry's regulations. The headmaster consulted his science staff and objections were communicated to the Director of Education, together with suggestions for the better utilisation of the space allotted. The plan was modified in agreement with the school's suggestions. With regard to lay-out and equipment of the individual laboratories, the architect's department, from first to last, consulted the headmaster on every point. He, in turn, consulted his science staff. The result of a series of conferences,

official and unofficial, between architect, county education officials, headmaster, and staff, was general satisfaction on all sides.

In the second case, the Education Authority of a county borough invited a science teacher to draw plans, including the science furniture and equipment. The assistance of the architect was available whenever required. The experiment was so successful that the same procedure has been followed in all cases of new laboratories erected subsequently by this authority.

### NUMBER AND SIZE OF ROOMS

Contrary to common belief, even small schools really require two laboratories, as practical chemistry, physics, and biology cannot easily be taught in one. It is difficult to do advanced work in a general laboratory which caters for the elementary work of the whole school.

For elementary work a special laboratory is sometimes provided, the heights of benches and stools being suited to younger boys. The general opinion is that such elementary laboratories are advisable only if the size of the school keeps the other laboratories reasonably fully occupied. The main difficulties associated with "all purposes" laboratories are those of time-tables, duplication of apparatus, and chemical fumes. One practical room for each science subject is probably more satisfactory.

Whenever biology is taught as a full subject it should have its own laboratory; otherwise difficulties occur in arranging space for living material, and in leaving experiments and dissections. In the absence of a biology room, a physics laboratory is to be preferred—the essentials being good lighting, flat-topped tables, wall sinks, wiring for lamps, and a suitable storage room. Some suggestions to this end will be found in the section dealing with biology laboratories.

The regulations of the Ministry of Education as to the minimum number and minimum size of science rooms in Grammar Schools are as follows :—

E—960 sq. ft. laboratory.      Z—540 sq. ft. lecture room.  
A—450 sq. ft. adv. lab.      P—230 sq. ft. preparation and  
store room.

Number of Pupils	Up to 160	300-330	460-490
Ministry of Education recommendations.	1E + 1P	2E + 1Z + 2P	3E + 1A + 1Z + 3P

It is at once obvious that if classes are to remain at 30, these laboratories are too small. Each practical room should cover 1,100 or 1,200 sq. ft., especially if apparatus has to be stored in it. If, however, the urgently needed reform that no class for practical work should exceed 20, should materialise, there would be no need for such large rooms.

The science master is in a dilemma. He feels strongly that he should press for half-classes, with consequent duplication of lessons. It is unreasonable to saddle one man with the responsibility of supervising as many boys in a laboratory as in an ordinary classroom. Since the opinion of the Ministry seems to be definitely against half forms, the teacher may have to accept whole forms and press for larger laboratories and additional free periods to cope with the work involved in preparation and in the running of a laboratory. The advanced laboratories suggested by the Ministry of Education are too small for sixth forms in large schools.

It is necessary to point out that the Ministry's recommendations are generally taken as maximum although they are minimum requirements. It is quite common to find that a minimum size of 960 sq. ft. is regarded as a space of 960 sq. ft. surrounded by rough brickwork. Plaster, wood, and other types of surface work are then allowed to make inroads on the 960 sq. ft. If the rough brickwork of a square room encloses a space of 960 sq. ft., plastering the walls to a depth of 2 in. means a loss in floor space of nearly 20 sq. ft. In other words, rooms supposed to be built to Ministry of Education requirements are commonly under size.

Detailed examination of answers to a questionnaire show that serious disagreement with the Ministry's recommendations occurs in the following cases :—

(1) *For Schools doing Physics, Chemistry, and Elementary Biology*

It is felt that schools of under 160 pupils require at least two laboratories with two preparation or store rooms. In effect, this means that the Ministry of Education minimum should be doubled.

Schools of 300-330 pupils require one laboratory and one advanced laboratory more than the rooms recommended by the Ministry of Education. Schools of 460-490 pupils require one advanced laboratory more than is suggested by the Ministry. Schools of 620-660 pupils require four 960 sq. ft. laboratories,



two advanced laboratories, three preparation or store rooms and two lecture rooms.

(2) *For Schools doing Physics and Chemistry*

Many feel that the large laboratory accommodation is inadequate, especially in the larger school.

(3) *For Schools doing General Science*

Similar complaints relate to large schools of doing General Science. In this case indeed not only is the number of large laboratories criticised, but serious difficulties are also encountered in making time-tables that will allow for the teaching of Science in the accommodation suggested by the Ministry.

(4) *For All Large Schools*

It is a general opinion that at least three preparation and store rooms are required in schools of 620-660 pupils.

For all schools the Committee believes that the maximum number of pupils in a practical science class at any one time should be 20.

### LAY-OUT OF SCIENCE BLOCK

Teachers of Science appear, in many cases, to have become resigned to laboratories whose lay-out and internal arrangements are laborious and badly conceived. Accordingly, it seems wiser to put forward constructive suggestions of a general nature rather than merely to reproduce a large number of plans.

In bygone years, it is probably true that all equipment was kept in laboratories, whereas nowadays much of it is stored in subsidiary rooms. Gradually, too, it is being realised that it is educationally and economically sound to make and repair apparatus at the school.

The more enlightened Education Authorities now provide at least one laboratory attendant for each secondary school, and there is a definite tendency to make accommodation for the science staff near to the laboratories. The need for preparation rooms and for dark rooms is generally realised.

Thus the number of rooms which used to be regarded as appendages now reaches considerable proportions, and it is high time that adequate attention should be paid to them in planning new schools.

Revolutionary though it may seem, there is much to be said for designing a central core of a science block consisting of :—

Preparation rooms and workshops.

Dark room.

Storage room or space.

Science staff room.

Battery and other subsidiary rooms.

The laboratories and lecture rooms could then be planned around this central core (Figure 1).

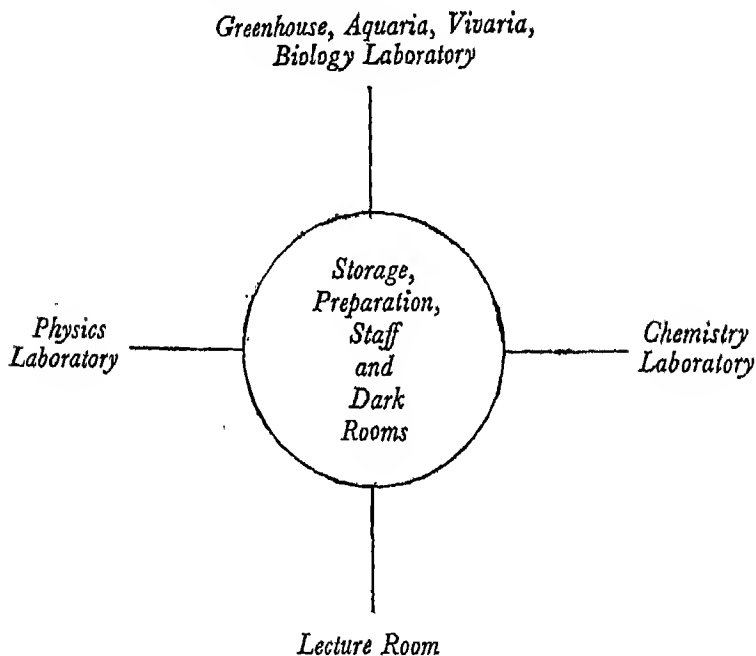


Figure 1.—Science Block with Central Core

The laboratory attendant would be well placed for service in any one of the surrounding laboratories ; the staff would be in much the same position, and apparatus and equipment could readily be taken to any of the surrounding rooms.

The exact details of doors and partitions in the storage, preparation, and dark rooms would depend on the nature of the surrounding rooms. The fumes common to chemistry practical rooms make it necessary that these should be isolated as far as

possible from laboratories and stores housing delicate apparatus, and also from Biology laboratories where living plants or animals are kept.

There might be two entrances to the block of buildings to avoid corridors. Then there would be a door from each laboratory to the centre section. One hatch per room would also be helpful.

With a guiding principle established, i.e. that storage, attendants', staff, and subsidiary rooms should be centrally placed with regard to all other science rooms, it would be easy to decide the relative merits of various designs.

For example the arrangement in Figure 3, showing three

<i>Preparation Room</i>	<i>Store</i>	<i>Chemistry Laboratory</i>	<i>Lecture Room</i>
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Figure 2.—An Arrangement of Science Rooms (one floor)

<i>Chemistry Laboratory</i>	<i>Preparation and Store Room</i>	<i>Lecture Room</i>
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Figure 3.—An Alternative Arrangement

adjacent rooms, is greatly to be preferred to the more cumbersome arrangement in Figure 2.

#### PLANNING OF INDIVIDUAL ROOMS

Too often the vital question, "What exactly is to be the purpose of the room?" is overlooked when laboratories are planned. It is recognised that the satisfactory planning of laboratories depends largely upon :—

- (1) Clear ideas as to the use of the room and of the work to be undertaken in it.
- (2) Wide knowledge of apparatus and materials.
- (3) Good judgment in deciding upon the most suitable compromises—successful laboratories are always matters of intelligent compromise.

If the room is to be a laboratory the following guiding principles will then be of value :—

The laboratory should be so planned that

- (1) each boy is readily accessible to the teacher ;

- (2) movement on the part of pupils and teacher is reduced to a minimum, i.e., it should be possible to assemble pupils easily for a demonstration. Each pupil should have bottles, cupboards, a sink, a balance, and a fume cupboard near to him ;
- (3) (i) the teacher can see what each pupil is doing ;  
(ii) each pupil can see what the teacher is doing by way of demonstration or blackboard work ;
- (4) the relative proportions of furniture and floor space are carefully adjusted. Something like 10 per cent. of the bench space should be allowed for special apparatus ;
- (5) all services are accessible, carefully designed and, as far as electricity, gas, water, and exhaust systems are concerned, controlled by master switches or taps in each room. Mains electricity connections should always be placed with a view to avoiding possible earthing through gas and water connections ;
- (6) storage room is allowed even when special rooms are provided.

The essential principles are shown in the following diagram :

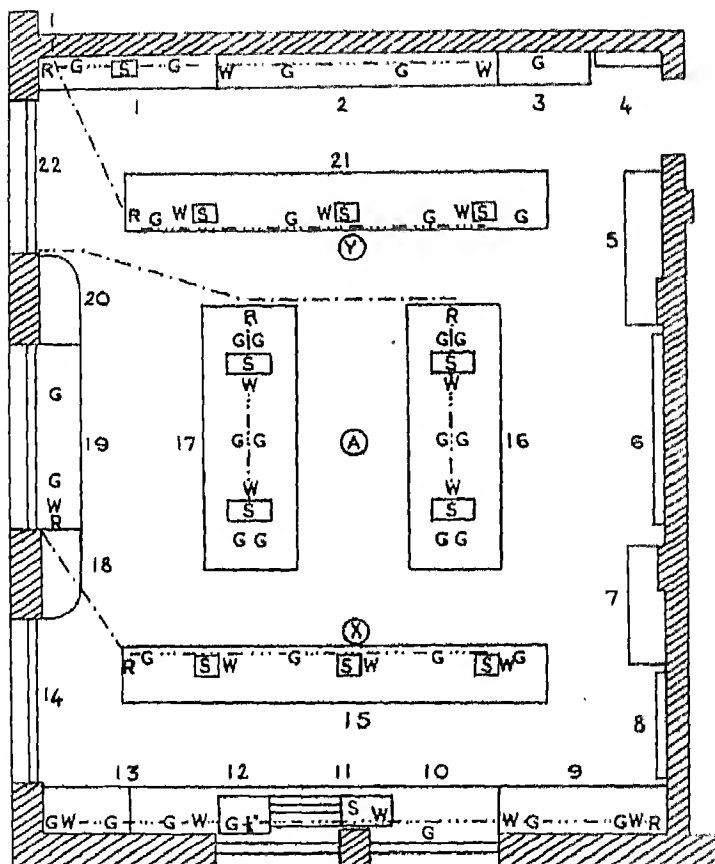
Detail :—

1. Bench, with shelves over, for long standing experiments.
2. Fume cupboards with no interior divisions. Storage cupboards underneath.
3. Balance bench with drawers and cupboard under and locked wall cupboard above.
4. Bottle shelves.
5. Balance bench with shallow drawers under.
6. Double sliding blackboard.
7. Balance bench with shallow drawers under.
8. Bottle shelves.
9. Fume cupboards.
10. Balance bench.
11. Sink and draining board.
12. Stone combustion bench with  $\frac{1}{2}$  in. gas supply.
13. Fume cupboards with no interior divisions.
14. Window bottle shelf.
15. Single bench with storage cupboards for unit system and drawers (unit system). Spaces also for waste boxes. Back of bench removable for drainage inspection.
16. } Double benches with set-back drawers and cupboards for storage on unit
17. } system. Spaces also for waste boxes. Removable parts for drainage inspection.
18. }
20. } Balance shelves with drawers under.
19. Fume cupboards with no interior divisions.
21. As 15.
22. Window bottle shelf.

NOTE.—The window positions were fixed before the furniture was designed.

A teacher standing at "A" could get to any pupil by moving a few yards.

A class of 30 could split into ten groups and use the fume cupboards without moving many yards.



Reference —...—... = Above-floor Drainage  
 —. —. —. = Below-floor Drainage  
 R = Receiver  
 W = Water Tap  
 S = Sink  
 G = Gas Tap

Figure 4.—A Chemical Laboratory

(Scale:  $\frac{1}{2}$  in. = 1 foot. Radiators not shown—mainly under windows)

## 24 TEACHING OF SCIENCE IN SECONDARY SCHOOLS

Fifteen balances are easily accessible without movement of more than a few yards.

Essential bottles are arranged on bench tops, those more rarely used are concentrated at "X" and "Y" and reserve reagents are placed on four sets of shelves, two of which are window shelves.

For demonstrations on the double bench in front of the blackboard, all pupils can see from their own places or move in a few yards to form a large circle around the two double benches.

There are no high obstructions between the teacher and pupils. One disadvantage (i.e., a compromise) is that about one-third of the class have to turn round to see the blackboard.

Doing without a demonstration bench allowed generous floor space throughout the laboratory.

This scheme, it should be noted, was made more difficult by the fact that radiators had been arranged around the walls before the furniture was designed.

### LECTURE ROOMS

It is important that lecture rooms should be planned as far as possible to allow every convenience to the teacher. His attention must so often be given to experiments that the room should be laid out to reduce :

- (a) Danger to the pupils ;
- (b) Disciplinary difficulties.

Separate single desks are therefore unquestionably an advantage, especially as they allow easy access to each pupil. The desks should be well separated from the lecture bench. Disciplinary troubles generally vanish when pupils are interested, and so every detail of every experiment should be visible to the boy.

Most science teachers would probably advocate the use of tiers in a lecture room, to make demonstrations visible from every desk. The most efficient arrangement is to have the tiers erected on concrete staging : from an acoustic point of view also, this is good.

### SERVICES FOR SCIENCE ROOMS

The following matters should be considered before the building plans are completed.

Heating ; Ventilation, Exhaust Pipes and Fans ; Lighting

and Dark Blinds ; Acoustics ; Water ; Drainage ; Pipe Services ; Gas ; Electricity ; Blackboards, Screens ; Wall Surfaces ; Floors.

### 1. *Heating*

The heating arrangements for science rooms should be regarded as part of the fittings. Far too often the heating installation takes precedence over all other considerations once the general plan of the room has been decided.

In most, if not all, science rooms the walls are required for experimental work, or as a back support for benches, cupboards, or shelving. In a physics laboratory it is particularly desirable that at least two walls out of the four should be available for experimental classwork. Further space may be required for the mounting of large diagrams, and for voltmeters, ammeters, clocks, transformers, distribution boxes, and other apparatus which should be clearly visible to the class. Ideally, the walls in science rooms should be clear of heating pipes and projecting appliances up to a height of at least 6 ft.

Heating arrangements for laboratories are generally applicable to other parts of the school, but the converse is not so true. For that reason comments are made on heating systems as seen by the science teacher.

In general, the heating of laboratories or science rooms is most satisfactorily carried out by any one or by a combination of the following methods, all of which depend on the circulation of water heated by coal, oil, gas, or electricity :—

- A. Direct convection type (hot-water radiators and piping).
- B. Ceiling or wall patterns of radiant hot water cast-iron panels.
- C. Radiant heating by invisible pipe coils embedded in ceilings or walls.
- D. Slow-speed suspended type hot-water unit heaters.
- E. Floor heating.

#### A. DIRECT CONVECTION TYPE

This method deserves serious consideration if only because of its cheapness. Many objections may be met by the adoption of some or all of the following devices :—

- (1) Fitting radiators at the ends of island or central benches, when these are not of the movable type.

- (2) Arranging radiators under portions of the outside wall not required for cupboards or experimental work.
- (3) Arranging pipes to run along walls just above the bench level, particularly under windows.
- (4) Making under-floor connections, under removable grids, between radiators.
- (5) Running pipes in the specially enlarged toe-spaces under benches.

#### B. CAST-IRON RADIANT PANELS

The fitting of ceiling panels is an attractive proposition to the designer of laboratories because this method leaves the walls clear of obstructions. Few schools have had experience of this method, but institutions which have installed overhead heating are generally enthusiastic about its merits. The system is said to work best when the air is cooled rapidly by contact with a large number of windows, although open windows at a high level may interfere seriously with its efficiency.

A special hydrated lime plaster should be used for the ceilings, which are subject also to rapid discoloration, particularly around the edges of the panels.

#### C. EMBEDDED PIPE-COIL PANELS

This form of heating is similar to that described in method B, the ceiling or wall surface being utilised as the heating area. Special types of plaster have to be used, and the water passing through the embedded pipe-coils is maintained at a low temperature to prevent rapid deterioration of the plaster work.

This method would undoubtedly be expensive to instal unless the remainder of the school were heated by similar means.

To the science teacher its attractiveness lies in the freedom which it allows for the use of wall space.

#### D. SUSPENDED UNIT HEATERS

Suspended unit heaters may be used when little or no space is available for radiators, and the building construction prohibits the use of methods B and C. The basis of the system is that hot water is circulated through small heating batteries. Air is blown over the battery surface by a small electrically-driven propeller or fan. The heaters work best when the circulation of the entire system is accelerated mechanically by an electrically-driven circulator.



## E. FLOOR HEATING

Floor heating may be arranged by fixing pipe coils under a floor of special construction. Even though this method seems particularly attractive at first sight, it cannot be recommended for two main reasons : (1) under-floor heating is more suitable for places where people have to sit down than it is for rooms where a good deal of movement is necessary ; (2) most laboratories require space under the floor for drainage, gas, water, and electricity connections. The multiplicity of connections under the floor would militate against efficiency, and sources of heat near to open drains in chemistry laboratories would add further complications.

### *Tubular Heating by Electricity*

This method is not commended because the warming process is generally slow. What is more important is that valuable "skirting" space is taken up by the units and there is serious interference with the placing of the furniture.

### *Panel Heating by Electricity*

The remarks on hot-water heating by radiators may be applied, very largely, to panel heating by electricity.

### *Heated Air*

The many advantages of the system whereby heated air is forced into rooms at a high level and withdrawn at a lower level may best be dealt with under the heading "Ventilation."

## 2. Ventilation

Properly designed natural ventilation is usually satisfactory except for dark rooms and rooms which have to be darkened in daylight.

Wall gratings behind radiators, Tobin tubes, and similar arrangements are common, but devices for deflecting currents of warm air into the room interior instead of towards the ceiling are not so usual.

It is desirable that direct draughts should be avoided even though the windows may be open, and the type of window illustrated in figure 5 has received most favourable mention because the windows can be opened in different ways according to the wind direction.

Window A is pivoted in the axis XX ; windows B and C are either side-hung or (better still) pivoted on the axes YY and ZZ. Window D is bottom hung. It is desirable to have arrangements for holding each window in any required position.

Strong draughts are not only undesirable from the point of view of the occupants of a science room, but also affect the efficiency of Bunsen burners and open balances.

Science blocks generally contain permanent dark rooms and also rooms which may be temporarily darkened for experimental purposes and for cinema and lantern displays. To ventilate these

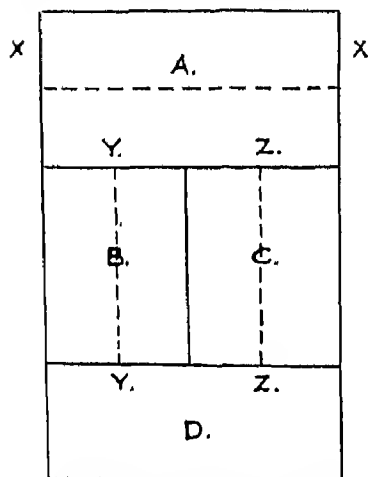


Figure 5.—Window Design to Avoid Draughts

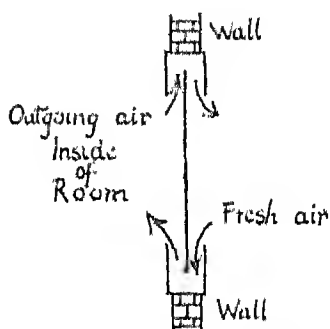


Figure 6.—The Ventilation of a Darkened Room

an arrangement for deflecting incoming and outgoing air by opaque material is illustrated in Figure 6. It has been known to work with reasonable efficiency.

#### EXHAUST PIPES AND FANS

Provision should be made in building plans for any mechanical arrangements required to withdraw air from chemistry laboratories and from fume cupboards.

Separate channels in walls are required when fume cupboards are fitted with burners setting up convection currents which clear away the fumes. The science block as a whole should not have its exhaust pipes on the side of the prevailing wind.

Electric fans are strongly recommended for all exhaust systems.

### 3. *Lighting*

Lecture rooms and laboratories are frequently arranged with windows on three sides. As a result either the pupils or the teacher must face a strong light. This is an arrangement which should be condemned because of the serious eye strain likely to result. Neither teacher nor pupil should be expected to face a strong light. In no case should windows be placed at the sides of a blackboard.

Ideally the best lighting is secured from windows arranged along the two long walls of a room. There should be no strong shadows, and the planning of benches ought always to be carried out in relation to the natural lighting.

Most laboratory windows should open outwards. There is much to be said for the swinging of upper and middle windows on different axes so that prevailing winds may be deflected to reduce draught. The louvre type of window has been found quite satisfactory for the lower sections.

All windows should be so arranged that dark blinds can be fitted to them should the necessity arise.

For chemistry and physics rooms, windows should extend from ceiling to bench level, except where there are wall benches, when they should end 6 ft. from the floor, as the wall space between them and the bench is valuable.

For Biology, north and sky lighting (with suitable blinds) is desirable; windows should come right down to the benches at least on one side and French windows even down to the floor are useful.

It is important to differentiate between general lighting and local lighting. General lighting by daylight must always take precedence over local lighting required for, say, fume cupboards. The occasional use of appropriately placed artificial lighting may be made to meet special illumination requirements.

Architects do not normally need to be reminded that light wall colours are desirable in schools. Dark browns, dark greys, and blues should always be avoided.

### ARTIFICIAL LIGHTING

Artificial lighting should be good enough for close work—at least 10 ft.-candles at bench level. The Lighting Service Bureau recommends 11–13 ft.-candles for laboratories and 4–6 for lecture

theatres. This requirement is probably low for school lecture rooms because of the writing, graphwork and sketching that have to be done there. Even then the lighting of the demonstration bench requires special attention.

Good lighting is especially necessary for the dissection of small biological specimens ; the foot-candle value for this work should be in the neighbourhood of 25.

The Technical Committee of the Illuminating Engineering Society (32, Victoria St., S.W.1) has issued a list of the illumination values recommended for various purposes.

Artificial daylight lamps are an advantage for colour work, especially in advanced chemistry laboratories. Lights over

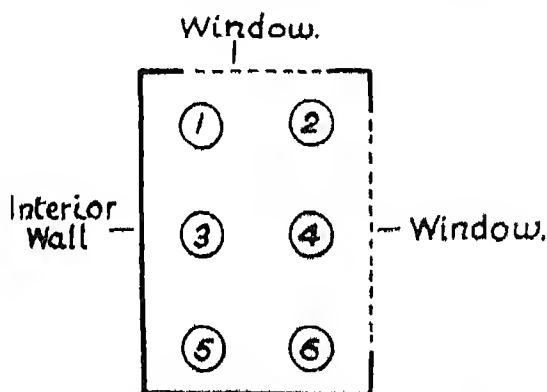


Figure 7.—An Arrangement of Artificial Lighting

benches in advanced laboratories and lecture rooms should be on pulleys so that their height may be varied from 2 to 8 ft.—the 2-ft. level is useful for biology.

Two laboratory lights are frequently arranged to respond to one switch. It is strange to notice how seldom any thought is given to which two lights should be so worked in a room which has a number of switches. The parts of a room more remote from the windows will require artificial lighting before the other parts. The force of this argument is illustrated by figure 7, in which the numbered circles represent artificial lights and the dotted lines window space. Clearly the working of lights three and five on one switch will be more economical in running costs than the wiring of five and six together and three and four together in separate pairs.

*Dark Blinds or Curtains* are necessary in at least one room. Many teachers would like them in several, e.g., lecture room, Biology, advanced Physics, and even elementary laboratories. Blinds should be of a specially light-proof composition, and the sides should run in deep wooden channels, painted dull black inside; otherwise the blinds blow out when the windows are open. Windows fitted with dark blinds must not open inwards; bars across will prevent bellying if the window is open.

A satisfactory form of dark blind is of the spring roller type, and pulls down. Instead of the usual trough for the blind to run in, both side pieces are hinged and felted. To pull down the blind, the hinged wooden side pieces are swung open, the blind pulled down, the cord fastened, the wooden pieces swung back, and small bolts shot home. The blind is gripped throughout its entire length; but the arrangement does not permit of window ventilation.

Ventilation through darkened windows may be secured by the use of blinds which run in 2-in. grooves and which overlap, one blind coming down and one being pulled up. If a 4-in. gap is left between these and an adequate overlap is provided, ventilation is possible. One firm supplies a dark blind, framed round, and working up and down in grooves, which can be fitted with a special ventilating head.

Wooden shutters are unnecessary and (in the opinion of the Ministry of Education) undesirable. They can, however, be arranged to allow of ventilation and can be supplied with wooden handles easily fitted into slots. Steel shutters running in grooves have been found satisfactory.

The advantages of blinds which unroll from the bottom of the window do not seem to have received adequate attention. They are particularly easy to deal with in case of trouble.

*Curtains.*—It is claimed by some that curtains have substantial advantages over blinds for the darkening of rooms. They are said to be much cheaper than blinds, they are easier to handle, and equally efficient provided they have a sufficient overlap at all points. It is, however, particularly important that the fittings should be the subject of careful and detailed specification. Curtains are often blamed for troubles caused by poor materials and inadequate overlapping on all sides. Many authorities are turning to curtains for the darkening of rooms for film projection. Curtains may be particularly useful in rooms with poor acoustic

properties. It should be remembered that it is not safe to store bottles within range of swinging curtains.

#### 4. *Acoustics*

The science of the acoustics of buildings has only been developed since 1900 and many—science masters and architects alike—know little of it. Its importance in schools is by no means always recognised. There are three main types of acoustic defect :—

- (1) Insufficient *absorption* of noise, leading to excessive reverberation which makes speech seem noisy and indistinct. This is the most common defect.
- (2) Excessive *generation* of noise (e.g., noisy floor).
- (3) Sound transmission.

(1) Excessive reverberation can be cured by treatment after the building is finished, but this is normally much more costly than the incorporation of appropriate arrangements in the original building. The treatment required can be predicted from the plans and data of furnishings, and if special treatment is necessary, it will probably take the form of special plaster on some of the walls or ceilings. Soft plasters and Celotex put on in sheets have proved useful. When the architect of a laboratory is not prepared to adopt modern acoustic treatment, special expert advice from a qualified acoustic engineer should be sought before starting the building. The National Physical Laboratory will give advice on specific problems.

For comfort and efficiency in class teaching the reverberation time should be considerably less than the normal approved minimum for speech. In large lecture rooms or laboratories with hard, smooth walls, the reverberation time may easily *exceed* the normal minimum unless special plaster or other treatment is used on walls or ceilings. (Even in a class-room 25 ft.  $\times$  25 ft.  $\times$  12 ft. with enamelled walls, speech may be very uncomfortable.)

(2) Attention should be paid to the generation of noise as well as to its absorption. Solid floors reduce the generation of noise, and devices such as rubber feet on stools help substantially.

(3) Noise *transmission* from room to room may be serious, and is not easy to cure. Concrete floors and glass partitions (even double) can transmit noise. A wall of another building facing the windows can reflect sound, and pipes can carry it.

Special care is needed in considering plans to avoid noise transmission. Special sound insulation is possible but expensive. Ideally, it should consist of several layers of two materials arranged alternately, one being dense, and the other highly absorbent.

### 5. *Water Supply*

The water requirements of certain laboratories may be large, and the size of the inlet pipe should be carefully calculated. In chemistry laboratories, for example, ten or twelve taps may be turned on at once, whilst water may also be required in other science rooms at the same time. It seems desirable, therefore, that there should be a good pressure of water. The use of water in one laboratory should not affect the pressure in other rooms.

It is worth bearing in mind that stop taps enable high pressure water to be adjusted to a much lower working pressure, should this be necessary.

Cessation or diminution of flow when several taps are turned on is usually accounted for by the service pipe from the waterworks main being too small.

### WATER TAPS

Revolving taps should be avoided as they are generally found to leak at the terminal point. Nozzles of taps should taper so that rubber tubes may be fitted on easily. A corrugated nozzle is an advantage, the actual end of the tap not being much more than  $\frac{3}{8}$ -in. in diameter.

Excessive pressure tends to cause breakages of glass apparatus. Devices for reducing splashing are essential, otherwise books and hot apparatus may be badly damaged.

Water fittings should be made of some non-corrodible material, such as gun metal, lacquered or oxidised. Chromium and cadmium plating and stainless steel may also be recommended. For most sinks it is wise to have at least one high and one low tap. The clearance for the high tap should be over 2 ft. so that burettes and Winchester quart bottles may be filled.

The water stream from a tap should clear the edge of a sink by several inches, and splashing is reduced if it does not fall directly on the grid over the waste pipe. A short length of rubber tubing fixed to taps produces a soft, even flow. The sink waste should not be directly under the tap.

Some taps should have a clearance of 3 ft. for long apparatus and others should be fitted with metal filter pumps.

### HOT WATER SUPPLY

Hot water should not be taken from a hot-water heating system. Many laboratories are fitted with simple geysers which give satisfactory service. A few schools have electrically-heated geysers, but these are thought to be more expensive to operate than gas-heated appliances. Electrical apparatus of this nature works well in atmospheres which are reasonably dry and free from fumes. In all cases it is desirable to consider the effects of fumes on the surface of any fitting that may be adopted. To prevent lime deposit in heating apparatus in areas where the water is hard, the only satisfactory method is to install a soft-water plant, or, failing that, to run the system at as low a temperature as possible.

### 6. *Drainage*

All sink outlets should be large enough to prevent flooding, even if all the taps are left on. Traps in the pipes immediately under the sink should be avoided and all sinks should be fitted with a removable grid of lead.

Standing overflows in sinks are serviceable, particularly because they prevent strong acid from going straight down the waste pipe. A vulcanite tube, ground at one end to fit into the outlet, is recommended. A second overflow outlet is desirable. The sink top should be level with the bench or well protected by the bench top. Care should be taken to ensure that the joint is watertight.

Care should also be taken over the connection between the sink and the waste pipe, as much trouble occurs at this junction. Brass should not be used in any circumstances. The outlet pipes from sinks should, in general, be wide, vertical, and without bends. In a chemistry laboratory, trouble may be expected at bends, and it is at the bends that lead piping is thinnest and weakest.

Separate sinks might feed into a semi-circular open drain of porcelain with joints reinforced by bitumen. A "V-" or "U-" shaped wooden trough has often proved satisfactory, especially if it is coated with a good thickness of lead and then treated with bitumen or some acid-proof material of a similar nature. This trough should be accessible easily. Open drains should not, under any circumstances, be made to turn at any considerable angle.



Too much care cannot be taken to ensure that solid matter does not get into the waste pipes. It is remarkable what a quantity of rubbish can be accumulated by apparently innocuous materials like filter papers and iron filings: special caution is needed should the laboratory be used for Biology or Domestic Science. It is essential that main drains should be open and easily accessible for inspection.

They may be half or three-quarter circular section and, in general, they should be at least 6 in. in diameter. Pipe fittings at the present time are generally too narrow. Earthenware, glass-lined iron, or other material covered with acid-resisting porcelain may be used. Main drains should generally be sunk under the floor with removable covers. They may even be uncovered in certain circumstances. The fall should be adequate.

### *7. General Remarks on Pipe Services*

Frequent difficulties occur as a result of pipes which are too narrow or too thin. The weight of piping per foot should be carefully specified, especially when it is to be used for water or drainage services. In no case should more than five 1-in. pipes be led from one 2-in. pipe.

As far as practicable, iron pipes should be avoided in Physics laboratories. Iron should never be used near bench surfaces.

It is the general opinion of science masters that pipes should not be placed:

- (a) above benches, except on walls,
- (b) in positions where pupils' feet can strain the connections, or
- (c) in inaccessible positions (e.g., under floors, unless adequate arrangements are made for access).

In cases where pipes are required to feed benches along the sides of a room, it is a sound arrangement to lead the pipes along the walls just below the level of the bench tops.

It is always useful to arrange pipe services so that individual benches may be cut off when local repairs become necessary.

Main stop taps should be placed in easily accessible positions near the door in each science room.

### *8. Gas Supply*

Gas meters should be fitted as near as possible to the position where the gas service enters the building. Control cocks should

be fitted in each room served by gas and a main control for the Science Block.

Laboratories can be fitted with copper or brass tubing and this is unquestionably desirable in physics laboratories but undesirable in chemistry laboratories.

### GAS TAPS

The double two-way form is desirable for laboratory gas taps, both lever and oval handles being satisfactory. They should be made of gun metal, tapered, with ribbed nose for tubing—to take  $\frac{3}{8}$ -in. rubber tube. They should be protected from accident under the front edges of benches and not sunk below the bench surface. Taps should be so placed that they are not likely to catch in clothes or to be turned on inadvertently.

One tap with large bore is useful for blow-pipe work ; for gas muffles,  $\frac{1}{2}$ -in. or even  $\frac{3}{4}$ -in. may be regarded as a minimum.

In some schools gas taps have been fitted in wooden boxes sunk below bench levels with flush lids. This arrangement is not recommended.

In biology, physics, and general laboratories it is sometimes desirable to have movable tables which occasionally require gas. In such cases, three arrangements have proved satisfactory :—

- (1) Gas taps on the walls at about 4 ft. above floor level.
- (2) Gas taps at about 4 ft. above the floor fitted on "light-houses" (mentioned in the Advanced Physics Laboratory section).
- (3) Gas taps sunk in wells in the floor. These wells have close-fitting lids with a notch cut in one side to allow the passage of a pipe when the lid is in position. In such cases the metal pipes should be arranged to run up the inside of the table legs so that the length of rubber connection required is not more than 6 in. The rubber above floor level should be protected from the feet of those working at the table.

Small bolts may be attached to two legs of the table which may be shot home into floor sockets when gas supplies are required.

### 9. *Electricity Supply*

With electrical supplies it cannot be too strongly stressed that every item should be carefully specified. It is not sufficient for

the suppliers to be given generalised statements and to be asked to work to them.

Electric wiring should be carried out with Association grade cable, preferably made by a member of the Cable Makers' Association.

These firms also make a cheaper type of cable that is known as non-Association grade, but for the wiring of laboratories the better quality Association grade cable is recommended.

The most suitable kind of insulation of the cable is the usual V.I.R. (vulcanised rubber). Where it is not likely to come into contact with chemical fumes, such cable can be installed in steel conduit tubing sunk in the walls in the usual way. In chemical laboratories, however, it is considered better to use V.I.R. cable protected by the standard lead alloy sheathing or by a tough rubber sheath, the cable being installed preferably on the surface of the walls. In such cases, where the outer protection is stripped, as in a joint box or other fitting, leaving a part of the rubber insulation exposed, the box should be filled with a suitable compound which can be obtained from any C.M.A. firm. Such precautions will ensure a long life of the electrical installation in the ordinary chemical laboratory where fume cupboards are provided for serious fumes.

Sizes of cable should be in accordance with the latest edition of *The Electrical Equipment of Buildings* issued by the Institution of Electrical Engineers, the current carrying capacity being as shown.

Flexible cords should be of the tough rubber-sheathed type and where the ends enter joint boxes or other fittings the receptacle should be sealed.

Plug sockets should be made in accordance with the British Standard Specification for the standard ratings of 2, 5, or 15 amp. carrying capacity. Sockets should be of the 3-pin or "earthing" type so that, where necessary, the metal frame or casings of electrical appliances can be properly connected to earth.

All demonstration benches should have at least two power points, preferably with 15 amp. plugs. In lecture rooms, points are also desirable at the back of the room and on the wall near the end of the demonstration bench.

It is wise to arrange distinctive plugs for mains and low voltage supplies, for example, if all main sockets require 15 amp. plugs then low voltage sockets might be suitable for 5 amps. If

5-amp. plugs only are issued to pupils there is no possibility of their damaging apparatus or themselves by plugging into the wrong circuit.

All 15-amp. and 15/5 conversion plugs should be in the specific care of the teacher. This is a most necessary precaution. 3-pin plugs are most desirable with high voltages.

The supply of electric current to benches for experimental purposes seems still to be in its infancy and no one system can be said to have been tried out and found thoroughly satisfactory by a large number of teachers. In the near future, all laboratories may expect to receive supplies as A.C. at 230 volts. Electricity will be available for lighting purposes and plugs should be supplied at selected points in the walls for heating and power purposes. The heating and power plugs should not be wired on the lighting circuits.

Low voltage Direct Current supply is very valuable. It can be used for optical experiments, micro-projectors, galvanometers, film slide lanterns and so on. It lends itself to simple experiments with fuses, ammeters, voltmeters, rheostats (Ohm's Law), and voltmeters, and is useful for the production of magnetic fields, the construction of electro-magnets and for heating experiments. It is safe and reliable. Usually such current is supplied from a bank of accumulators charged by a motor generator or some form of rectifier. In some cases, elaborate wiring systems have been arranged to supply different voltages. Multi-volt arrangements are not generally popular because—

- (1) A suitably chosen fixed voltage supply can be made to do most of the experiments possible with the more complicated system.
- (2) The uneven discharging of accumulators makes recharging a complicated business which requires a great deal of time.
- (3) Their value is not sufficient to justify the expense involved. Fixed volt systems, on the other hand, can be made very simple, and so comparatively inexpensive.

Valve rectifiers adequately protected by fuses can be used to charge a bank of accumulators (say 100 amp.-hrs.), and during holidays the accumulators can be trickle charged. It is wise to keep such banks of accumulators in a special well-ventilated battery room, which can also be used for general storage. Gas

points are not desirable in this room. Accumulator makers will suggest suitable rates of trickle charging to fit individual requirements. The advantages and disadvantages of using nickel-iron or similar accumulators should be considered.

In estimating the necessary capacity of an accumulator it has been found useful to base the calculation upon the assumption that the installation should be able to supply 3 amps. for 2 hours at each student working place.

It is now possible to get good motor generators to supply reasonably steady current as and when required. They are not expensive and give no trouble. For Wheatstone bridge and potentiometer experiments small accumulators are still necessary—30 amp.-hrs. is generally considered an adequate capacity. These are best charged from a Westinghouse copper oxide or other rectifier plugged into the mains. Such rectifiers give no trouble and require little attention.

Motor generators produce a certain amount of noise. If a motor generator is fitted it should be *outside* the laboratory and bolted to a concrete bed with a thick rubber pad between the bed and the motor. Little or no noise will then be heard in the laboratory. The switch-board with voltage control, ammeters, voltmeters, and fuses or automatic cut-outs may be inside the laboratory. The dynamo should be compound wound, with series cut-out-switch so that it can be run as a shunt-wound dynamo for charging accumulators.

The choice of voltage seems to lie between 12 and 25. If the pupil is given a suitable rheostat to place in series with his apparatus he can control his own voltage (with 12 volts—a variable rheostat of 15 ohms resistance passing 5 amps. is very suitable).

In favour of 12 volts, we have the fact that very suitable lamps for 6 volts (two in series or with a rheostat) and 12 volts, of suitable size and power for most optical experiments, can be obtained cheaply. The voltage is sufficient for demonstrating magnetic fields, for voltmeters, for electro-magnets, and for most general experiments. Against this must be set the fact that manufacturers are not keen to make 12-volt dynamos, the field magnets being sometimes slow to excite. The voltage drop in a large laboratory, especially with ammeters and voltmeters in circuit, is considerable (e.g., it may fall to nine) and the voltage fluctuations with a class of pupils switching their apparatus on and off is considerable, necessitating constant attention to the

switch and rheostat control. Some teachers regard this as an almost insurmountable obstacle : others feel that the variations provide most useful teaching material, the consequent advantages outweighing the inconveniences. With 25-volt supply these

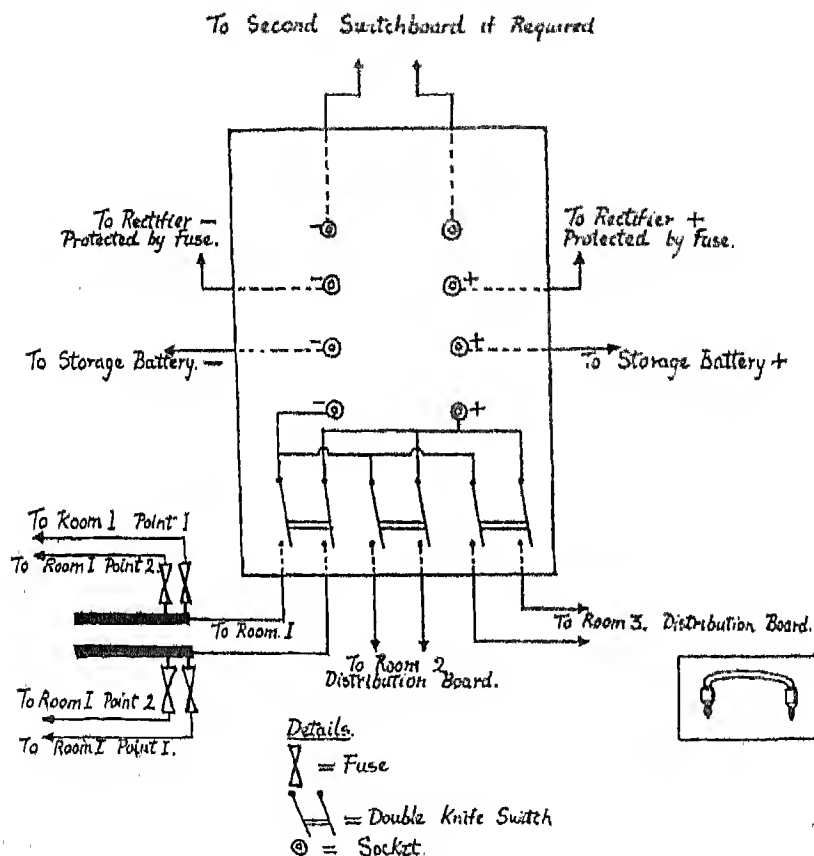


Figure 8.—Power Distribution

Sockets can be connected :—

- (1) To charge storage battery (from Rectifier)
- (2) To feed rectifier supply direct into room (rarely required)
- (3) To feed battery supply to room
- (4) To feed rectifier or battery supply to a second switchboard

difficulties are not so serious, but on the other hand the lamps are large (standard size lamps and lamp holders have to be used) the voltage is too high for many purposes and requires large and clumsy rheostats in the circuit.

The machine should furnish from 50–100 amps. according to the

size of the laboratory. An ordinary plug on the bench is sufficient, with looped cable wiring—*large sized cable*—from bench to bench. The electric plug should *not* be near the gas taps, electricity supply or water pipes or taps. A distributing board which can be connected to plugs is useful.

For inside benches, dark rooms, etc., to which the low voltage system is not carried, small transformers can now be bought cheaply to supply either 6 or 12 volts A.C. for small lamps and these are very useful. It is strongly recommended that some definite voltage (say 12 to 25) should be chosen. All apparatus and lamps may then be selected or adapted to suit the chosen voltage.

A number of useful experiments can be performed using the mains supply with Variac transformers.

It is desirable that the whole system should be adequately, even excessively, protected by fuses, and the teacher should have in each room a fuse board or a series of automatic cut-outs governing each individual point of supply to the students. A suitable arrangement is shown in Figure 8.

An alternative method, using Cycloc units, gives a wide range of voltage in A.C. or D.C. without the use of accumulators.

#### ADDITIONAL NOTES ABOUT ELECTRICAL INSTALLATIONS.

(1) All cables should be metal-covered up to at least 1 ft. from the ground.

(2) Cab-tyred conductors should be used where possible for temporary wiring.

(3) Accumulators should be stored in a room without coal gas supply.

(4) Generous sizes of cables should always be used.

(5) It is wise to adopt a definite convention, e.g., + sockets always on the top or the right-hand side.

(6) Accidents have occurred owing to mistakes of contractors in wiring electrical installations, e.g., reversing wiring from meter, or putting switches in neutral instead of live wire.

#### 10. Blackboards, Screens.

*Area.* There is a general demand for as large a blackboard area as possible, but there is little agreement as to the actual sizes, which vary from 5 ft.  $\times$  2 ft. up to 7 ft.  $\times$  4 ft. 6 in.

Generally speaking, blackboard space behind the teacher's bench should be as large as possible. Pupils cannot normally see blackboards which extend below 3 ft. 6 in. from the floor. Teachers should not be expected to write at heights above 6 ft. from the floor or platform level.

*Type.* Many teachers favour sliding types, either sash types or those which slide sideways. The sash sliding types permit of white wall surfaces, lantern screens, or fume cupboards being concealed behind them. In hanging sash-boards the cord, which should be specially strong, should be fixed to the *tops* of the blackboard and the pulleys must be fixed higher than the highest point which can be reached by the corner of the blackboard.

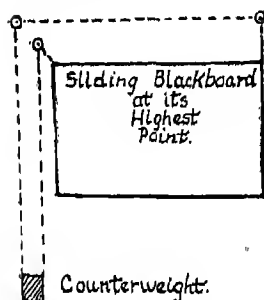


Figure 9.—A Sliding Blackboard

If this is not done, as the blackboard rises, the corner of the board with the attached cord quickly rises to pulley level and then rises *above* it. Thus the weight is first lowered quickly and then pulled upwards suddenly, producing too great a strain on the attachment to the board and on the cord itself. This is a trouble which is far too common. It is said that blackboards which have both sides attached to the same counterweight do not stick unless the cords give too much (see Figure 9).

Fixed types of blackboard are also recommended and are undoubtedly cheaper than the sash-hung types, since they require no elaborate suspension apparatus. They should slope forwards from the top and it is convenient to have them in reversible sections, which should not, however, be too narrow. The complete board should be from 6 to 12 ft. wide by 4 ft. high.

Roller types, fitted at the top to a roller-blind fitting and below to a wooden roller and suitable catch, are sometimes used. The material used is black "American cloth" or green linoleum. An ingenious roller type consists of an endless band of an American cloth type of material running over narrow rollers fixed at the top and bottom of the available space. In such fittings ease of movement is important. Blackboard cloths or thin boards with or without special rulings can be hooked to hang in front of the usual blackboard.

*Position.* Behind the demonstration bench is the generally



accepted position, though the end of the laboratory is also possible. Lino or Celotex-board panels around the walls are suggested in addition to a large board behind the master's bench.

*Surface and Material.* The green surface material is highly recommended. There is a difference of opinion on the subject of glass. Some praise it highly, though the back may have to receive occasional attention ; others regard it as too heavy and hence prefer wood. In any case, glass will be serviceable only with fixed blackboards.

The surface of wood may be matt, egg-shell finish, and painted with a special black paint.

Slate is also suggested but is very heavy. Linoleum in panels can be used and also American cloth on rollers.

*Ruling.* Generally ruling is not required, except perhaps in physics laboratories where part of one board might be squared in inch-squares for graph work. This may be done with cellulose enamel. When sectioned boards are in use, one or more might be squared on one side only.

It has been suggested that a ruled board is used very infrequently and that a ruling might be projected temporarily on a plain board by a lantern or a wooden or lino graph-ruled blackboard hung when required over the permanent board.

## SCREENS

Many people use a wall surface painted white or even a white ceiling. Others prefer a roller-fitting with a dust flap at the top of the roller framing.

Aluminium paint has not proved successful, but stippled aluminium-surfaced cloth is recommended. A three-ply board, sized and dusted with aluminium powder is recommended by one architect.

Ordinary white sheets are useless if the surface is unprepared. Three-ply, painted with "Ceilingwhite," is easily renewed and quite satisfactory in use. White cardboard is useful with micro-projectors.

## II. Wall Surfaces

For certain rooms, such as mechanics laboratories, brick, distempered, but unplastered is suggested. It collects dust,

however, if it is not well pointed. A brick laboratory gives an impression of coldness and discomfort and the aesthetic side of a laboratory should not be overlooked.

Wood to a height of 6 ft. at least has been fitted in certain laboratories, especially for Physics. It has the advantage of deadening echo and reducing heat losses.

Hard compressed felt treated with non-inflammable compounds has been used. Sheets of cork all round the room at eye level and above it have been found particularly useful for the display of diagrams, especially in Biology. One school has walls of asbestos sheeting.

Wooden strips about 12 in.  $\times$  1 in. fixed flat along the wall parallel to the floor, and about 4 ft. from it, may be used for a multitude of purposes.

Dark colours should be avoided in science rooms, except perhaps in the dado where stains due to accidents would be less noticeable on a brownish background. Stains in chemistry rooms are often yellow or brown in colour.

Colours and surfaces should be so chosen that the reflective power of the wall is good ; tiles or glazed bricks to a height of at least 3 ft. are recommended for chemistry and preparation rooms.

In chemistry laboratories lead paint should not be used. Hydrogen sulphide causes the formation of black lead sulphide which ruins the decorative effect of lead paints. It is a safe rule to use only zinc or titanium paints in science rooms. In this connection it is interesting to record that iron nail heads are said to show through zinc paint. All iron and steel surfaces in chemistry laboratories ought therefore to be painted very carefully.

Picture rails at a considerable height above the floor may prove useful in lecture rooms and laboratories.

## 12. Floors

Floors in science rooms should not be noisy, slippery, unduly hard, or cold. In chemistry laboratories the surface should be such that it will not be unduly marked by small quantities of acid and alkali, and it should withstand considerable quantities of water.

For advanced physics laboratories some particularly firm flooring is necessary because of the apparatus which requires a stable foundation.

On the whole, science masters seem to prefer wood for flooring.

Wooden blocks are generally preferred to floor boarding provided the blocks are so fixed that they do not work loose. The preference for wooden boards shown in certain quarters is due to the fact that they are less tiring to the feet than many types of block floors. Boarded floors are better where access to parts under the floor is required. Pitch pine or hardwood boards are recommended, the boards being tongued and grooved and sunk nailed.

Wooden blocks which have proved satisfactory have been made of hard wood, oak, jarrah and teak. In all cases they should be carefully laid with pitch on a concrete bed and with adequate allowances for any expansion that may occur. The blocks may be treated with preservative (linseed oil and wax) but should not be polished.

Granwood, concrete and wood composition, stone compositions and rubber composition have received favourable comment in certain quarters. Granwood is the flooring recommended where there is underfloor heating.

*The National Builder* for February 1936 quoted the following reply from the Building Research Station :—

“In considering the type of floor finish suitable for a laboratory, it should be borne in mind that not only acids, but other types of injurious substances also may be present, so that an essentially acid-resisting material may not be capable of withstanding all the agents likely to cause harm.

The requirements, as regards acid resistance, for the floor of a school chemical laboratory are not so stringent as with the floor of a chemical works which may be subject to continual action of deleterious substances. In a school it is reasonable to suppose that any acids spilt will be immediately wiped up.

It is therefore possible that a good quality cork linoleum would be sufficiently lasting to admit of consideration. Actually, alkalis would be more harmful to this than acids. If the linoleum were kept polished a certain amount of additional protection would be afforded.

As an alternative, an asphalt finish could be laid successfully over the existing deal floor, and would resist both acids and alkalis. This type of floor can now be obtained in various colours and finishes and would have the advantage of being continuous. It would, furthermore, be possible to dress the asphalt around fittings, which would give increased cleanliness and would facilitate the washing down of the floor.”

The Forest Products Research Laboratory says : " There can be no doubt that for chemistry laboratories Australian Jarrah (*Eucalyptus marginata* Sm.) would make the best wood-block floor. This wood is exceedingly acid-resistant and is also heat-resistant. For acid-resistant floorboards we would recommend Burma teak. For physics laboratories where the absence of joints and a smooth surface are obligatory, it might be advisable to look into some of the newer composition floors which are now being made, and also special coverings of a rubber type."

The Corkboard Research Bureau have investigated the possibilities of cork tiles, which can be laid on almost any sub-floor and are generally put down in some geometric pattern and wax polished. The tiles themselves consist of highly compressed and baked cork granules and are extremely durable.

Adequate arrangements are always necessary to secure the accessibility of under-floor services and drains. Normally it should be possible to examine such services without waste of time and without the use of screwdrivers or other tools. Many of the special materials involve considerable difficulties, and additional cost, in dealing with this essential requirement. There should always be room under the floors for additional services.

Where an upstairs laboratory has a false floor, the lower floor should be covered with asphalt and have an outlet. This arrangement saves damage to lower floors by flooding.

### 13. Other Matters

General outlines of the furnishing scheme should be drawn into the preliminary plans, so that adequate allowance may be made in the final plans for the entry of gas, water and electricity services at appropriate points. Allowance should also be made for under-floor services and drainage systems. Exhaust systems should also be arranged for in the final plans.

#### ROOFS

Glass roofs make rooms unduly cold in winter and hot in summer. In general, they should be avoided. The bearing of roof materials upon the temperature and acoustics of a room should be borne in mind.

### DOORS

Usually laboratory doors should open outwards. They should be wide to allow rapid clearance of a room in case of emergency ; large laboratories should have two doors.

### HATCHES

Hatches between preparation rooms and adjoining lecture rooms and laboratories are frequently useful. If they are fitted they should have a shelf on both sides.

### ELECTRIC BELLS AND TELEPHONES

Bell pushes near to a blackboard with a bell ringing in the appropriate preparation room are particularly convenient. Some science masters have fitted internal telephones between the laboratories and the preparation rooms. They should not be necessary if the laboratories and preparation rooms are adjacent to each other, as they should be.

Telephone communications between science rooms and other parts of the school are of doubtful value. There is more to be said for internal communication between the office and the preparation or science staff room.

## SPECIAL ROOMS

### 1. *Storage and Projection*

#### A. STORAGE

The problem of storage is a serious one : few laboratories contain enough cupboards to house the large and varied stock of apparatus and materials under the science master's care. Such cupboards as exist are often too deep, taking two or more ranks of apparatus or bottles ; the shelves are too far apart or too close together, or not long enough to accommodate awkwardly shaped articles.

A general scheme must first be devised. In many schools, physics and biology apparatus is kept entirely in the respective laboratories and the store room used for Chemistry only. If there are two store rooms, one may be allocated as a " wet " store and the other as a " dry " store—the former containing acids and solutions, the latter chemicals and reserve apparatus.

One large school finds the following arrangement very satisfactory :—

Bench drawers and cupboards for articles in frequent use.

Wall shelves for standard solutions and reagents.

Wall cupboards for beakers, flasks, etc.

Store room reserved for demonstration and fragile apparatus.

*Bench Cupboards and Drawers.* There is a general opinion against storage of apparatus in benches : many schools use bench cupboards for non-breakable apparatus only : a few use cupboards for complete sets of pupils' apparatus, especially in Chemistry and Biology : drawers are occasionally useful for small equipment. Regular supervision is necessary to see that apparatus is clean and unbroken and that drawers and cupboards do not become receptacles for rubbish.

In laboratories where the benches face the demonstration bench and are used on one long side only, the other side may be utilised for additional cupboard-space : such cupboards may be unusually long.

*Wall Shelves.* These are almost unanimously condemned, chiefly on the grounds that they collect dust and that the wall space so occupied is valuable. An exception can perhaps be made in favour of bottles in a chemistry laboratory and here much breakage may be saved if the bottles are secured by a thin rail, especially in cases where the laboratory is also used as a classroom.

*Wall Cupboards* are the best means of storage for apparatus in the laboratory. These may be carried as far up the walls as is convenient : they need not be, as a rule, more than 9 ins. deep, but to give the necessary length for sonometers, Wheatstone's bridges, potentiometers, etc., two cupboards may communicate with each other. To encroach as little as possible on the laboratory space, double doors may be provided. Shelves should be adjustable or fixed at varying heights to suit different classes of apparatus ; Boyle's Law tubes, coefficient of linear expansion apparatus, etc., require tall cupboards. (The space between windows is sometimes useful for such things : the tops of wall cupboards may serve for long apparatus.) It is often advantageous for one cupboard to consist of a chest of drawers of various depths.

There seems no special advantage in having glass fronts, but it is useful to have wall cupboards backed. When glass fronts are

used, it adds appreciably to the light of the laboratory if the backs of the cupboards are painted white.

*Special Apparatus.* Some kinds of apparatus of special shape or size require separate treatment. Long narrow glass articles, like pipettes or burettes, can be stored in shallow trays or drawers lined with cotton wool, or fitted with suitable racks slotted to prevent rolling and breakage. Thermometers should be kept vertical, e.g., in a tall tin of convenient diameter. Small physics apparatus such as lenses and small compasses are best kept in drawers divided into compartments or in shallow trays. Bar magnets are conveniently kept on boards similar to drawing boards but narrower: compass needles on sheets of card, postcard size, with cuts into which the ends may be fitted. It is convenient to have the entire stock for the use of a form kept in one container designed for the purpose: this arrangement also makes checking after a lesson much easier. Trays which can be removed entirely, with their stock, are thus often more useful than a drawer of equivalent depth. Lamps, discharge tubes, and other fragile apparatus can be stored in a strong box lined with cotton wool and divided by partitions.

*The Container System.* We would stress the advantage of the container system, partly to prevent breakage of glass articles easily chipped when stacked *en masse*, but principally because of the ease of carriage into the laboratory for distribution, and for convenience in checking, which may be done at a glance. It is specially suitable for small articles like specific gravity bottles, weighing bottles, glass blocks and prisms, mirrors and lenses, rulers, magnets, compasses and resistances. A strong tray with plywood partitions to suit the articles, and numbered spaces to correspond with these, will serve and can be made in the workshop. For lenses, etc., linen bags may be used. Shallow trays, sliding on supports or in grooves of cupboards, are useful for burettes, pipettes, condensers, etc. For specific gravity bottles a lid pierced in holes to fit over the necks (like an egg box) will save much breakage. For carrying flasks, beakers, etc., to and fro, shallow tray-boxes can be made which will hold the number desired—these slide easily into their places, between  $\frac{1}{4}$ -in. or 1-in. strips or guides.

Vertical storage is useful occasionally. Thus stands can be made for thermometers to rest in parallel inclined grooves:

or for burettes, which stand (upside down) through holes in a top shelf and over pegs on the base of the stand. Wooden racks with slots may be used to store some articles so that they hang upside down to drain : this method is suitable for measuring cylinders and for burettes if the slots are fitted with rubber rings to grip them.

The uses of the container system are not confined to movable carriers : the system can be applied to containers which cannot be moved, and can be incorporated in existing cupboards, which might contain hooks for spring balances and pulley blocks, slots for hydrometers, and so on.

*Diagrams.* These may be stored flat in a large picture frame with a movable back and glass front. When one is required it is brought to the front and the others replaced behind it, the back being closed and fastened : the frame with contents hangs on the wall. Another way is to use a deep locker under the bench : the diagrams, on thick paper, are displayed by suspension from large spring paper clips hung from screws fixed near the top edge of the blackboard. Two more clips serve as weights to keep the diagrams flat, if required. Rolled-up diagrams may be kept on a pair of japanned hooks fastened into two wooden uprights nailed to the wall. Numbering and indexing are essential, so that any required diagram can be quickly found.

*Arrangement of Apparatus.* Some definite scheme should be adopted : it is an obvious convenience to have all apparatus dealing with one subject, and likely to be required at one time, collected together in one place as far as its varying size will allow. Also articles most frequently required—rules, thermometers, glass-ware—should be in the most readily accessible spots. A neat system of labelling is often useful, but not essential if the arrangement is sufficiently systematic.

Bottles of chemicals may be arranged alphabetically or in the order of the analytical groups, with a special section for organic substances. Space must be left between the shelves for the taller bottles, especially those containing liquids. Labelling on the shelf front is useful.

*Balances.* These present a special problem of storage : a separate balance room is needed only for Chemistry. In the absence of special accommodation, wall shelves or even window sills are often used, or there may be special balance benches



18 in. wide at the far end of the laboratory. Another useful place where three or four may stand is a narrow shelf or bench in front of the demonstration bench and below the level of the top. Shelves in wall cupboards at a suitable height for weighing may also be used.

Two suggestions which have been found satisfactory may be made here ; one is to use one side wall below windows for a shelf 12 in. wide to carry a row of built-in, wooden, glass-topped cases 14 in. high and each 16 in. wide ; the fronts may open by vertical sliding doors, or be hinged at the top with a stop to keep them in place when open. The other is to use the thickness of a wall backing on a corridor in a similar way, the backs in this case being of glass. Weight boxes should be kept inside : a shallow drawer under the shelf is useful but otherwise the space should be kept clear.

For all work involving careful weighing, special balance tables consisting of a 2 in. thick York stone slab, placed on brick piers with good foundations and clear of the walls of the building so as to avoid vibration, are recommended.

## B. PROJECTION

Both a lantern and an episcopes are desirable, the latter to project solid or opaque subjects ; the two are often combined in one instrument, an epidiascope, and this is usually preferred, except for experiments in light.

*Lantern.* This should be open between the condenser and the projection lens to accommodate large objects instead of slides : facilities for projecting horizontal objects are also required.

*Epidiascope.* Useful fittings are a pointer in the instrument and a table which will easily swing out of the way to enable projection of an article held in the hand. There must be working room under the instrument so that dissections in progress can be projected.

*Micro-projector.* This should be a separate instrument as micro-projector attachments to lanterns are not usually satisfactory. It is essential that it can be used both horizontally and vertically. Some method of cooling must be available if living animals are to be projected.

*Film-projector.* Relatively few schools possess a film-projector ; under modern conditions every school should have one. A small

projector to take film slides or film strips is most useful for classroom work. For this, science masters' own illustrations can be made up or film slides can be hired.

*Position of Projector.* Various suggestions have been made in regard to the position of the lantern or projector.

(1) At the back of the class, with the screen on the wall, possibly hidden by a sliding blackboard until required. This is useful for a lantern lecture; it has the disadvantage that an operator is required.

Details of one such installation are as follows: two counterpoised blackboards of wood with a specially painted surface, each 7 ft. wide and 4 ft. deep are made to slide between two uprights 14 ft. high, one board being behind the other. When both boards are pulled down to within a few inches of the floor they leave exposed an area of wall 7 ft. square within the framework of the blackboard. This area is suitably painted and constitutes the lantern screen.

(2) At the end of the bench or on a wall near the end of the bench, permanently fitted up for instant use. A roller screen across the corner or swivelled in the centre of the room from the ceiling is required.

(3) A combination of both of the above, the bench lantern being used with a smaller screen.

(4) A screen (or two shutters) which swings round to cover a window.

(5) It is sometimes possible to arrange for the screen to be in a darkened part of the room so that projection in daylight is possible.

(6) The projector might be on a run-about table with wheels for use at either end of the bench.

## 2. Laboratories

### A. CHEMISTRY LABORATORIES

Most chemistry laboratories conform to one or other of the general types of layout, shown in Figures 10 and 11, which do not include special fitments.

These designs may include demonstration benches. Such arrangements or variations of them appear to give general satisfaction but we are inclined to believe that they are

laborious and might be developed on much more labour-saving lines.

Consider in greater detail Figure 4 (page 23) ; it is noticeable that the gangway space throughout the room is good, an essential feature in chemistry laboratories. The single benches have removable backs enabling drains to be inspected.

Nearly all the fume cupboards have large cupboards underneath which are used for the storage of glass and earthenware. The front sashes of fume cupboards are normally 3 ft. wide, but where several fume cupboards are placed next to each other

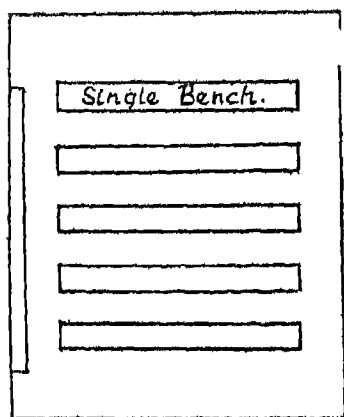


Figure 10.—Chemical Laboratory with Single Benches

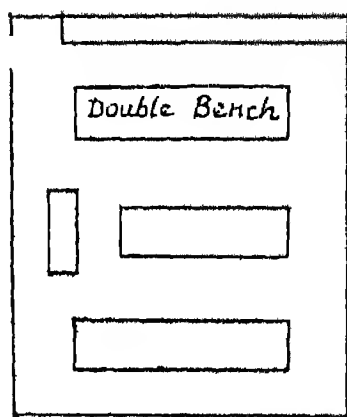


Figure 11.—Chemical Laboratory with Double Benches

there are no internal divisions. All fume cupboards are fitted with a tap well coated with bitumen paint and either a sink or a leaden funnel outlet. Gas and water are controlled from outside. Each fume cupboard has electric light shining through the glass at the top.

The exhaust pipes are made either of galvanised iron, elaborately coated with acid and fume-proof preparations, or of asbestos cement piping. The electric fan exhaust is placed in the roof and since it has to serve several rooms on one floor, the main controlling switch is placed in the Preparation Room.

A bench about 7 ft. long and 2 ft. 6 in. wide is arranged with sink, gas, and water taps and underneath storage for

exceptional work which might be required to remain standing for some time.

Bottles are concentrated in four main places, two of which are on the window shelves and the other two are placed near corners of the room. Each bottle place is labelled so that every bottle is returned to its right place. All bottles are standardised in size and this makes a distinct improvement in their appearance. In addition, as mentioned previously, certain bottles are available for each individual set of boys and bottles containing materials which are used fairly often, such as litmus and lime water, are concentrated at about the middle of the single benches, so that no pupil has to move far to obtain one of these reagents. A stone slab is fitted against the side wall of the room next to a sink drainage board. A muffle furnace and still are normally kept on the stone slab. Hinges which fold back flush against the wall are kept behind the sliding blackboard. These can be extended at right angles to the wall and then serve to support a flat sheet of asbestolite about 5 ft.  $\times$  2 ft. Experiments which involve risk of danger can be performed on this temporary table with the advantage that no boy is nearer than about 10 ft.

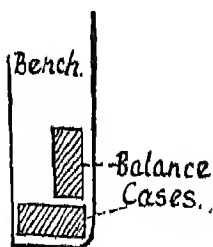


Figure 12.—An Arrangement of Balances

Small benches with shallow drawers underneath are used at many points on the wall for balances. Two balances can be arranged for simultaneous use in a space of 2 ft.  $\times$  2 ft. 6 in. if they can be set at right angles to each other. (Figure 12.)

Drains are accessible throughout the laboratory, which also has control taps for water and gas services. An accessible fuse-board controls the 14 volt D.C. supply fed to 12 points in the laboratory.

All wiring is well protected by cab-tyre insulating material and bakelite fittings are used.

A fitting behind the blackboard enables the electric fan to be switched on to a room exhaust fitted in the ceiling. All the fume cupboards can be exhausted electrically and each has a small door controlling the exhaust arrangements.

Shelves are fitted above one radiator and a sink and draining board are placed in front of another; it is necessary to arrange the sliding blackboards in front of a third. There is a generous allowance of shallow sub-divided drawers for pipettes, burettes,

and similar apparatus. Benches are fitted with subdivisions so that each working place has a complete set of apparatus, each piece of which fits into a predetermined space.

Although not shown on the plan, most of the water and gas pipes are arranged to run in the spaces above the drainage system. The pipes are coated with bitumen.

Fittings shown in Figure 13 are useful where space is limited. A balance may be fitted on a shelf. Storage accommodation may be arranged under, and wall cupboards may be arranged over, the balances. It is desirable that there should be some arrangement to ensure that the sliding sashes of the balance cases will not interfere with the opening and closing of the top wall cupboards.

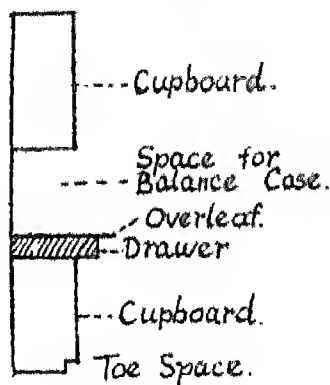


Figure 13.—Space Economy in Fittings

### *Chemistry Benches*

Benches may be single, all facing the master, or double; neither should be too long. The back and sides should overhang and there must be toe-space and enough knee space, at least at intervals, to allow of writing in comfort. A drawer, flap, or slide is desirable for books, and drawers for small apparatus. If cupboards are provided (useful for seniors) they should be shallow (one layer).

A waste box must be provided and also accommodation for a bench-swab. Accessibility of the drains and other supplies is vital and can be well secured if the front of a fixed bench is easily detachable.

Many teachers do not want shelves for reagents on the benches but would like an inlaid glass, porcelain, or tiled surface for essential reagents, the rest being at the ends of the benches or on the walls. For seniors a raised shelf might be fitted; but such superstructure must not obstruct the master's view.

There should be at least one double water tap for each pair of students and these might be at the end of small benches or distributed along the bench top in longer benches. The provision

of an additional circuit for filter-pump use is convenient, particularly for seniors.

Burma teak or Rangoon teak are unquestionably the best types of wood for chemical bench-tops: but iroko (African teak—*Chlorophora excelsa*, Bentham and Hooker), properly handled, makes a very good substitute.

Wood for chemical bench-tops should not be less than  $1\frac{1}{2}$  in. in thickness when finished. The wood should be plain sawn, and obtained in as wide widths as possible, preferably as wide as the bench so as to avoid long joints on the working area. If the benches are to be placed in a centrally-heated building, the woods should be seasoned to a moisture content of approximately 12 per cent. Before actually fixing to the bench carcasses, the tops should be laid in position and allowed to condition in the finished building as long as possible. Fixing of the carcass when finally carried out should be done by means of slotted screw-plates, so as to avoid restricting lateral movements in the bench-top, which may be accompanied by buckling and splitting. Seasonal movements must be expected as a consequence of humidity changes.

*Treatment of Bench-Tops.* After fixing in position, bench-tops should be well soaked in raw linseed oil. When this has been absorbed, and the surface is no longer "tacky," the benches should be rubbed down with beeswax dissolved in turpentine. The only maintenance which such bench-tops require is an occasional dressing with beeswax and turpentine.

*Materials for Under Parts of Benches.* No rigid restrictions are necessary in dealing with materials for the under parts of benches. The exposed parts of cupboards and drawers could quite well be of pitch pine, beech wood, Baltic red wood, or British Columbia Douglas fir. This last makes excellent framework, joinery, and cabinet parts, and may be obtained in this country in a number of different grades suitable for different situations.

The insides of drawers and cupboards could well be made of American basswood (*Tilia glabra*). Agba is now being used by some manufacturers.

If solignum is to be used for the backs of cupboards, there may be some risk of the inside coat of white paint being stained in the neighbourhood of joints.

### *Fume Cupboards*

The great majority of science masters prefer fume cupboards with mechanical draught electric fan, the ducts being of asbestos material and the motor external. If a flame draught is used a separate channel to the room is needed for efficient working.

They may be situated conveniently in a window opening to the exterior or might be shared between two adjacent rooms. They are better distributed along the sides of a laboratory, not only at the corners.

Slate is the best material for the base. The walls should be tiled, there should be a sloping glass top and sliding window, and they may be fitted with cupboards underneath. Gas supply with exterior taps is desirable and also a water tap and sink.

Lacquered fittings corrode badly, but aluminium paint has proved a good protection. Chromium plating might be tried.

There appear to be two opinions as to the number of fume cupboards required: one suggests six and the other ten as the number of pupils to share each fume cupboard; but some schools now have one for every three senior students. On the other hand, a few teachers dispense with them almost entirely except for Kipp's apparatus. When several fume cupboards adjoin, partitions between them should be avoided, so that a large experiment may be accommodated. In advanced laboratories there should be one fume cupboard to every two boys; a suitable size is 5 ft. front by 3 ft. depth.

### *Stools*

These should have no backs and be fitted with rubber soles if of the legged variety. The most popular seem to be of the four-legged type with shaped seats, though more than one height should be bought to suit different ages of pupils: 22 in. and 24 in. are suggested. Sharp edges should be avoided. The adjustable-height screw-type do not give universal satisfaction.

Stools are stored very conveniently under tables or under the overhang of bench tops; this should be borne in mind when designing benches, tables, etc.

It is useful to have the fit-over style, with metal legs, from the point of view of storage.

*Advanced Chemistry Laboratories*

In the planning of an advanced chemistry laboratory it is necessary to remember that the students will be considerably older and there is less reason to avoid bottle shelves and the like, which may be erected on double benches.

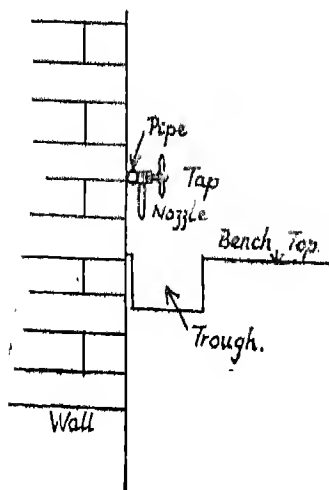


Figure 14.—Sectional View of Wall Fittings for Water Taps

Individual storage accommodation here becomes a matter of importance. Fume cupboards should be really large, say 5 ft.  $\times$  3 ft., with adequate drainage, water, and gas services. The blackboard space need not normally be as large as in an elementary laboratory.

For certain organic experiments, fittings are connected to several water taps at the same time and there may also be several tubes delivering into sinks. For this reason a wall fitting on the lines shown in Figures 14 and 15 may be a convenience provided the trough has been carefully fixed, is adequately protected and is arranged to reduce splashing to a minimum.

It is an advantage to have one bench with a hood and outlet

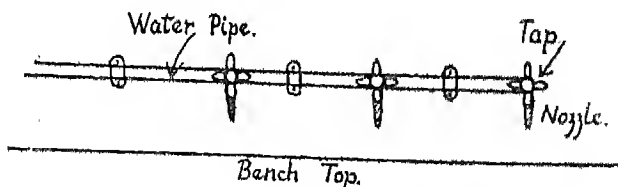


Figure 15.—Front View of Wall Fittings for Water Taps

for combustion. The hood may be made locally from galvanised sheet and covered with an acid-proof preparation. A large white tile may conveniently be let into a bench surface at one or more points for titration work.

An adjustable "daylight" lamp over each bench is also an



advantage, particularly when the laboratory has to be used in the evening.

## B. PHYSICS LABORATORIES

The stock designs generally include large tables, the number of which varies from four to eight. (Figure 16.)

Designs similar to those under the heading Chemistry are not uncommon.

An interesting design which incorporated the use of two walls for mechanics is shown. (Figure 17.)

The right-hand and bottom walls were fitted with removable  $\frac{3}{4}$ -in. steel rails at a height of 6 ft. About 2 ft. lower were removable boards about 1 ft. high and 4 in. from the wall surface.

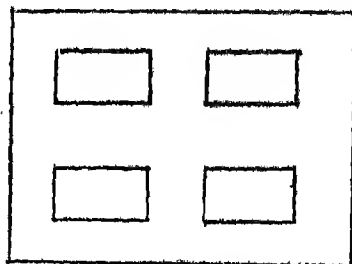


Figure 16.—Plan for Physics Laboratory

The rails and boards were so arranged that strings passing over pulleys attached to the rails would fall just in front of the boards on which drawing paper could be fixed. Pulleys could also be fitted through holes in the walls. The right-hand and bottom walls were boarded to a height of 6 in. for further experimental work.

A 1-ft. shelf was fitted on the bottom wall to carry (14, 16) balances, which were removed when Mechanics experiments were being carried out. Temporary flaps could be pulled out from these shelves to hold boxes of weights. An automatic stop prevented the flaps from being inadvertently pushed in again. A wooden girder (5) was attached to the piers on the right-hand side and could be used for experiments requiring extension. A steel girder which could carry a load of 3 tons was erected 3 ft. from the ceiling, in front of the lower wall (13).

Two of the tables (2) were removable, but when gas was required they could be fixed to the floor by driving a small bolt into a socket fixed on the floor. Gas was obtainable by making a rubber connection from the protected taps in the wells in the floor (3) to the permanent gas pipes on the table legs.

It was possible to arrange a good deal of storage space in the tables fitted in the room by fitting a drawer and cupboard well set back under the middle of each table. These drawers and

cupboards were used for the storage of apparatus frequently used, such as stands, tripods, asbestos mats, and the like. Drawers at the end of the table were used for laboratory storage, e.g., one contained pulleys mounted on racks, another contained weights, and so on.

The long bench on the left-hand side of the room (11) could be used by pupils if necessary. It could also be used for experiments required to stand for some time. Shelves were attached to one of

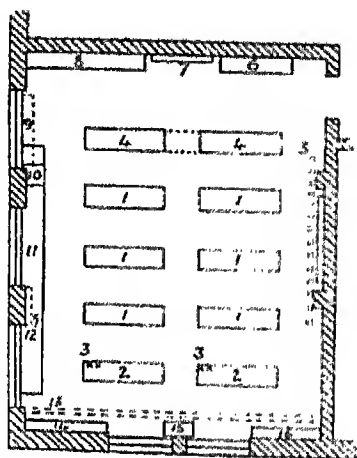


Figure 17.—An Elementary Physics Laboratory

(Radiators (under windows) are not shown. Scale:  $\frac{1}{4}$  in. = 1 foot).

the piers, 2 ft. above the bench, on which laboratory reagents were stored (12).

Flanking the double-sided blackboards (7) on the one side was a long teak bench (8), 1 ft. 6 in. wide with shallow drawers under. These were used for the storage of burettes, small solids and the like. Balances normally stood on this bench.

Electric fuses were arranged in cases at a higher level. On the right-hand side (6) was a storage cupboard, 7 ft. long, 2 ft. deep, and 7 ft. high. The lower part had no shelves, apparatus being fixed in containers already arranged for it. The upper part of the cupboard had a series of removable shelves with glass sliding doors. Throughout the laboratory the container system was used so that it was obvious at a glance if any single piece of

apparatus was missing. In many cases, the containers were strips of wood fitted to the floor of a cupboard, or to a shelf; in others they consisted of sub-divided trays.

The stools were fitted with rubber castors and could be stored

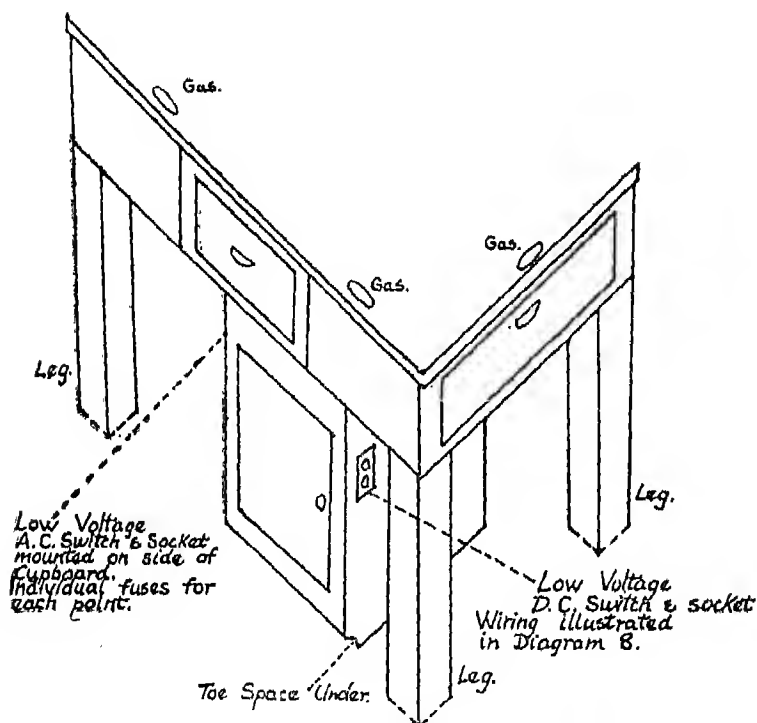


Figure 18.—Details of Physics Laboratory Tables

(Items 1 in Figure 17) (Items 2 in Figure 17: same as above but with spaces under table i.e. one cupboard in each table for student's use and two additional gas points and main plugs were fitted on the table shows the position of a flap which could be raised (and bolted) to make one long bench for demonstration purposes).

under the benches. The laboratory, it should be noted, was planned according to the minimum requirements of the Ministry of Education.

Each table was fitted with two double gas taps and also with 14 volt A.C. and 14 volt D.C. (Figure 18.)

Water was obtained from two sinks, one fitted with a draining board (10) and the other attached to a pier on the bottom wall (15). A drying cupboard (9) was mounted over the radiator.

One of the important points of design is that a teacher standing in the middle of the room could move to any pupil quite easily.

An arrangement was made at one school whereby an elementary physics laboratory could be utilised in several different ways by the adjustment of comparatively light tables.

Figure 19 shows the arrangement for demonstration work in Physics with the tables closed up. The boys sit on tansad chairs specially constructed to be of suitable height.

Figure 20 shows the arrangement for photometry, with long runs of tables in straight rows. The room had a transverse curtain at XX made of black Italian cloth. It was found that photo-

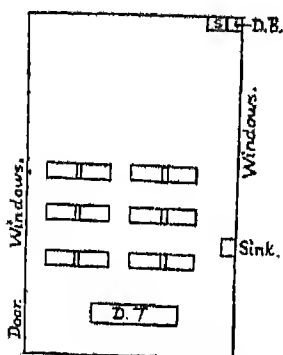


Figure 19.—Tables Arranged, for Demonstration Work

S = Sink

DB = Draining Board

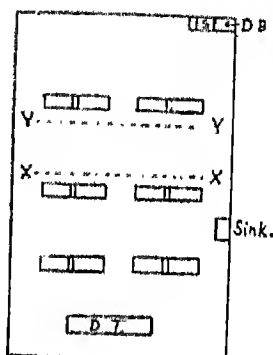


Figure 20.—Tables Arranged for Photometry

DT = Demonstration Table

graphy with certain materials could be carried on in half the room while the remainder was fully lighted. The physics master responsible for the design suggests that another curtain at YY would provide a perfect little dark room for sixth form individual work.

Figure 21 shows the arrangement of the tables for work with lenses, using accumulators which supply two or four pairs. This arrangement is also suitable for lens and mirror work by the non-parallax method, the eye looking the length of the room and so not facing the light nor losing sensitivity.

Figure 22 shows typical table groupings for individual experiments in the sixth form.

The window shelves are of standard height and could, therefore, be used in conjunction with the tables when absence of vibration

was particularly necessary. The arrangement was particularly useful in cases of experiments such as those on Newton's rings where some local semi-darkness was necessary. In this case the appropriate blinds, which had rollers at the bottom, were raised to 2 ft.

At another school, one of the wall benches in each of the physics laboratories has been covered in with black-stained match boarding. Along the front of the cover, curtain rails are arranged on which run dark double-thickness curtains with wide overlaps. The bench is fitted with gas and electric connections and all optical and dark-room work (photometry, mirror galvanometer,

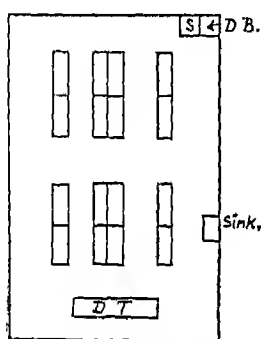


Figure 21.—Tables Arranged for Lens Work

S = Sink

DB = Draining Board

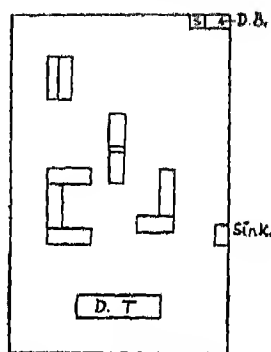


Figure 22.—Tables Arranged for VI Form Work

DT = Demonstration Table

spectrometry, ray projection apparatus, interference and diffraction) can be done on this bench by two or three workers or pairs. This form of optical dark room has been found very valuable, since the boys using it are working in the same room and at the same time as others doing ordinary experiments. A small photographic dark room is necessary and is, in fact, available when complete darkness is required.

One school supplies gas to its benches by arranging a trench under the floor, from which movable arms about 3 ft. 6 in. long can be rotated to a vertical position to feed gas to tables. When the gas is not in use the pipes rest in the trench under the floor and are covered by a removable lid.

Except in cases of extreme necessity, tables should not be arranged with one end fixed against a wall. Some physics laboratories contain desks, but the Committee believes that

practical rooms should be reserved, as far as possible, for practical work only.

### *Physics Benches*

Tables are normally preferred to benches and should have wide, flat tops, mounted on stout legs to ensure rigidity, and not be too high. The tops should overhang all round from 2 to 4 in. A height of 2 ft. 10 in. is desirable for elementary laboratories.

*Materials.* On the question of materials, reference should be made to the comments on chemistry benches.

A cheaper timber which is hard wearing and has proved satisfactory for bench-tops, especially in physics laboratories, is Canadian yellow birch, which may be obtained in good widths and of the desirable thickness.

Where bench tops have to withstand water and non-corrosive liquids only, the choice of material need not be at all restricted: beech and birch, for example, may be used. The precautions mentioned in the chemistry bench section relating to seasoning, conditioning, fixing and finishing would apply.

*Cupboards* are not required under all tables, but they might be used on one side and so might unit cupboards, suitably sub-divided.

*Drawers* are acceptable if set back to allow writing with comfort, and might be combined with a clear shelf underneath on which books could be put. Blocks of drawers at one side are suggested.

A long wall bench is valuable and also slate slabs in walls, possibly above bench level, for galvanometer use. So are galvanometer corner shelves at 5 ft. or 4 ft. 6 in. from the floor. At least one bench without iron is useful and it is desirable to reduce iron everywhere, especially near the surface: but elaborate attempts to avoid magnetic effects usually fail.

Gas should be supplied and the benches wired for L.T. supply: but water is not essential. Few sinks are required for Physics, and these are best on side walls.

*Stools.* Attention is drawn to the remarks on stools in the section headed "Chemistry Laboratories." The rectangular type has much to recommend it, especially in physics laboratories, where observations may need to be made with the eye at bench level and the pupil in comfort. This is attained by having the

stool made so that it can be used on its side. The rectangular type store well, and if the rungs are at different levels can suit various leg lengths.

### *Mechanics Apparatus*

There is no very general demand for the use of heavy mechanics apparatus outside engineering laboratories, although several schools use industrial models of apparatus such as Weston's differential pulley block. It is necessary to have clear ideas of the amount of heavy apparatus that will be used before planning the laboratory layout. In physics and elementary mechanics laboratories it will generally be found sufficient to have one girder support parallel to a side or end of the laboratory, with clear space for suspended apparatus. The ends of the girder may be embedded in two opposite walls or the girder might be attached to the ceiling. It is useful to have a bench, at least a foot wide, fixed against the wall and under the beam, so that apparatus fixed on one side can rest on the bench and on the other side hang clear of it. Normally the bench could be used for storing balances.

For such apparatus as Young's Modulus, Weston's differential pulley, pendulums, ballistic pendulums and longitudinal coiled springs, a wooden beam (supported by an iron T-girder) fixed to the wall at intervals by brackets and built into the wall at each end, is useful. Any supports can be screwed into the wooden beam. Most class experiments on pulleys, inclined plane, etc., can be performed on the bench, with the frameworks of heavy retort stands and cross-pieces supplied by all manufacturers of apparatus, although many of these systems are expensive. The advantages of arrangements which utilise clamps attached to the benches will be obvious to all teachers who have had experience of this type of work. Apparatus is easier to arrange if geometrically true clamps and boss heads are used. Many elaborate fittings have been suggested, fixed to ceilings or walls, but it is doubtful if some of these justify the expense. In all cases of proposed overhead girders or beams for suspending apparatus the architect must be consulted and the arrangement adopted must depend largely on the design and layout of the laboratory.

It should be pointed out that arrangements which enable pulley, parallelogram of forces, pendulum, and similar experiments to be carried out by boys around the walls of a laboratory, have the effect of increasing the useful area of a laboratory.

Arrangements that have been found useful include :—

- (1) Wooden beams supported on girders built into the walls at right angles to the beams.
- (2) A girder across the end of the laboratory—3 ft. from the wall, 10 ft. 6 in. from the ground, with movable supports for apparatus.
- (3) Bolts built into walls at suitable intervals to which either vertical or horizontal bars can be fixed.
- (4) Tapped sockets embedded in a concrete ceiling ; into these supports can be screwed.
- (5) 2-in. boards arranged parallel to the wall and 4 in. from it.
- (6) Various arrangements of vertical and horizontal wooden strips in sizes such as 4 in.  $\times$  2 in., 2 in.  $\times$  2 in.
- (7) Arrangements of  $\frac{1}{4}$  in.,  $\frac{5}{8}$  in., 1 in., and similar size steel rods parallel to and 4 in. from the wall surface.

All supports parallel to a wall should be fixed clear of the wall.

### *Advanced Physics Laboratories*

The most modern practice in advanced physics laboratories appears to be one which allows great mobility by confining working space, as largely as possible, to movable tables.

Fixtures may be limited to a few galvanometer shelves at a height of about 4 ft. from the floor, possibly a rigid shelf for balances, sinks, draining boards and preparation space. Such shelves are not a necessary feature of new schools. The use of galvanometers is changing and most schools are now buying sensitive galvanometers to place on the benches.

It is wise to secure tables of a standard height, say 3 ft., although an exception may be made in the case of a table required for writing, when 2 ft. 6 in. would be more suitable.

The size of the tables should be determined by the experiments which will be performed on them. They can, of course, be grouped into any desirable arrangement and the position varied at will. It is probable that most science masters will agree that the most convenient sizes of tables would be 3 ft.  $\times$  3 ft., 4 ft.  $\times$  3 ft., and 3 ft. 6 in.  $\times$  2 ft. 6 in.

Electric supplies should be arranged at frequent points around the walls. Gas taps may also be arranged on the walls or pick-ups may be arranged from the floor. It is important to remember that there should always be a considerable distance between



a mains electric point and a gas tap, unless the gas tap is made of insulating material.

A "Lighthouse" arrangement near the centre of the room has been fitted in a few schools of recent years and it has proved very useful. It may be utilised as a distributing centre for all electric services and gas. Here again it is important to remember that the gas tap should be made of insulating material. Ebonite serves the purpose quite well.

As in all other science rooms, all electric fuses, the main gas tap and the main water tap should be fitted in accessible positions, inside the room.

A blackboard is essential and it is also wise to include a storage cupboard, although this may be avoided if a preparation and store room is adjacent to the advanced laboratory.

#### C. BIOLOGY LABORATORIES

Many useful points relating to the planning of biology laboratories are brought out by the description of the plan in Figure 23. Attention is also directed to the comments on materials suitable for use in chemistry and physics benches.

##### *Notes on Plan of Biology Laboratory*

The tables 6 ft.  $\times$  3 ft. are moderately heavy and movable, with no gas, electricity, or water supplies, no drawers or cupboards. In the plan they are arranged for a demonstration lesson, in which case four boys might be accommodated at each table. For practical work boys could sit on both sides and tables could be moved to the window if necessary.

The *side and back benches* (same height as tables, i.e., 30 in.) may be fitted with drawers and/or cupboards, at intervals; the back bench might with advantage be made of slate.

The *demonstration bench*, height 3 ft., should be supplied with water, gas, and electricity, and should be fitted with drawers and cupboards. If there is no greenhouse, Wardian cases might be fitted to one or more of the windows on the south side. The windows, preferably French windows, open outwards at least for the lower half, and all windows are fitted with dark blinds.

*Benches.* There seems a preference for tables rather than benches, a suitable size being 6 ft.  $\times$  3 ft.  $\times$  30 in. high. Round the walls there should be fixed benches with sinks 12 in.  $\times$  18 in.  $\times$

8 in. deep. More sinks (and especially one large sink) should be provided for seniors, for whom benches are to be preferred. A long bench by a large window which comes right down to bench level is very desirable. Tables should be of a suitable

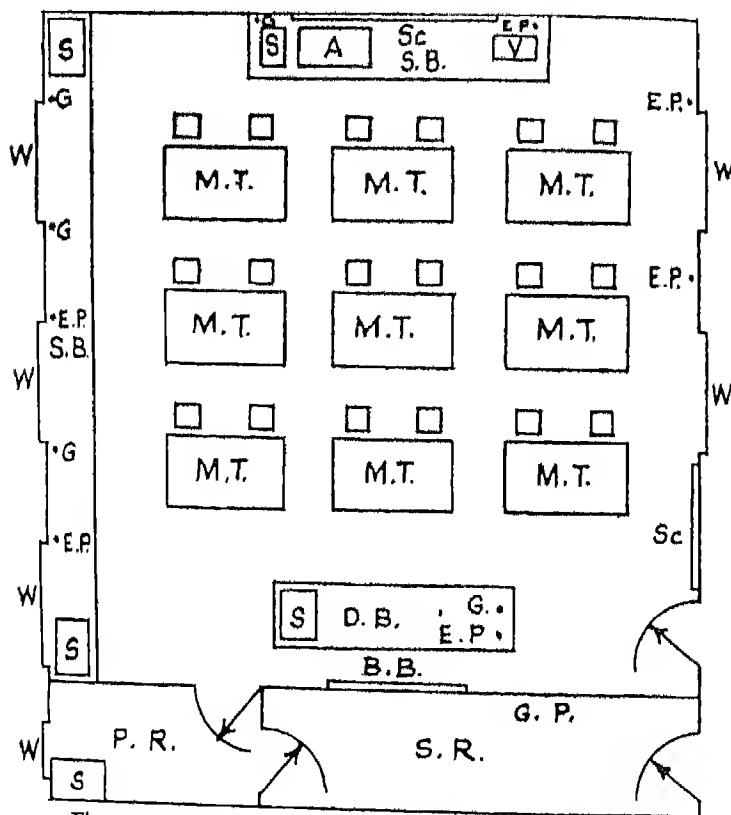


Figure 23.—Plan of Biology Laboratory (Scale :  $\frac{1}{8}$  in. = 1 foot)

Details :—

A = Aquarium  
S = Sink  
G = Gas Tap  
V = Vivarium

Sc = Screen  
MT = Movable Table  
BB = Blackboard  
PR = Preparation Room

DB = Demonstration Bench  
EP = Electric Point  
SB = Slate Bench  
SR = Store Room

height for microscope work, usually 2 ft. 6 in., that is, lower than for ordinary physics and chemistry experiments.

There should be no cupboards to obstruct knee room, though a few cupboards are useful in benches for seniors.

A good direct north light is essential, with provision for individual electric lamps for microscope work. Gas supplies

are required—one double tap per pair of pupils. There should be many drawers available in the laboratory. A bench, adequately supported, is needed for aquaria and should have the necessary water supply and drainage.

Stools should be 24 in. average height and should be provided with shaped seats and rubber buffers on the legs.

*Adapting an Existing Laboratory for Use as a Biological Laboratory.*

Many masters in schools where Biology has recently been introduced find they have to use a room originally fitted for other purposes. Also, in many schools where new laboratories are being built, one is definitely equipped as a dual-purpose laboratory—the usual combination being Biology-Physics.

The following notes suggest additions or modifications to facilitate biological work, but adaptation will naturally depend on the original lay-out and equipment of the room.

North light is desirable, but at least one south window is useful and the room as a whole should be warm and sunny to hasten growth and development of living specimens. A long bench should run the whole length of the laboratory on the window side.

Efficient dark blinds are necessary for work with the micro-projector and epidiascope. In a physics laboratory there are usually adequate gas taps and electric points, but often insufficient water taps and sinks. At least one sink per six boys is necessary for Biology, and one sink per four boys is desirable. A long, narrow bench, slate topped, is useful for aquaria and vivaria—often a balance bench can be adapted by the addition of water supply and drainage. Fume cupboards, if present, often make useful vivaria. If no greenhouse is available a south window could with advantage be replaced by a Wardian case.

Wood or cork strips fixed to the walls are useful for pinning up diagrams. A large, white plaster screen 8 ft. square, should be applied to the wall at the opposite end of the room to the demonstration bench. A lath framework slung to the ceiling by pulleys is useful for large charts or diagrams. This should be to one side of the blackboard.

#### D. LABORATORIES FOR GENERAL SCIENCE

The increasing attention being paid to General Science, and the growth of Biology teaching in the schools must necessarily affect our views as to what is the ideal laboratory accommodation

for any particular school. There is little doubt that in large schools a general science laboratory for junior forms is desirable. In small schools economy may force the adoption of dual purpose laboratories. We desire to emphasise, however, that in our view really adequate science accommodation in a school must involve separate laboratories for Chemistry, Physics, and Biology.

In new schools, the problem should be envisaged before the laboratory arrangements are settled ; in existing schools some sort of adaptation will often be necessary to enable Biology to be taught. There is at present little experience to guide the design of either all-purpose or dual-purpose laboratories, and all that can be attempted here is to offer some suggestions which may assist those who have the opportunity of experimenting.

### *All-Purpose Laboratories*

Except possibly for junior forms in a large school, *completely* all-purpose laboratories would seem to be impracticable. In any attempt to design an all-purpose laboratory, attention should be given to the following points :

(1) It is necessary to have very clear ideas concerning the purposes for which the laboratory is to be used, just as it is highly desirable to plan courses, before attempting to work out the equipment.

(2) It is clear that an all-purpose laboratory requires much more space than one designed for one subject only. The whole of the working space should not be in use at any one time.

(3) The equipment of other laboratories in the school should be taken into consideration. It is not likely, for example, that many schools would be able to duplicate heavy mechanics apparatus, dark blinds, and fume cupboards.

(4) The most serious difficulty to be expected is the action of chemical fumes on biological specimens and delicate physical apparatus. The isolation of living material in window cases would be helpful, though it must be admitted that temperature differences are likely to cause trouble. Covering with bell-jars would probably suffice for plants and all but the most active animals.

A partial solution of the problem of the all-purpose laboratory might lie in the direction of a chemistry laboratory capable of adaptation, e.g., by covering the sinks and storing the bottles on wall shelves or in removable carriers.

*Dual Purpose Laboratories*

A dual-purpose laboratory is a more practicable proposition. It might be designed (*a*) for both Chemistry and Physics, (*b*) for both Physics and Biology. With two such laboratories it should be possible for any school of moderate size to arrange a complete general science practical course. All the experimental chemistry would be done in one laboratory and all the experimental (indoor) Biology in the other, the physical work being divided between the two laboratories. The need for a laboratory assistant would be more than usually urgent. The organisation of practical work would be made easier if the same teacher were responsible for the whole of the general science work of one form.

The essential requirements for a dual-purpose laboratory appear to be :—

- (1) Large working space.
- (2) Generous storage accommodation.
- (3) Flexibility of furniture arrangements.
- (4) Adequate equipment.

In view of the many uses to which the room will be put, the planning becomes largely a matter of finding the most generally suitable of differing requirements. For this reason special fittings of all kinds must be considered with exceptional care, particularly in cases where they might interfere with the conduct of work for which they were not specially designed.

Accommodation should be planned on a generous scale, and the science master should press for the largest possible area, in shape square or nearly so. The Ministry of Education's figures for bench width and elbow room should be regarded as absolute minima, and every attempt should be made to make passage ways as wide as possible. At the same time, it is a safe guiding principle to reduce as much as possible the distance which a student will have to move in the course of his work.

In any laboratory designed for the teaching of more than one branch of science, it will generally be found desirable to allow adequate bench space for reserve purposes. If the laboratory is being used for a physical experiment, then the reserve bench might be used to store biological material required for the next lesson. Such bench space is also useful for the storage of apparatus for experiments which cannot be completed in one period. Some teachers prefer wide shelves for this purpose.

The following general remarks on the requirements for dual-purpose laboratories are added :

(1) Some provision for demonstration is essential, which in the absence of a lecture room may be met by the provision of a demonstration bench. The fittings need not be elaborate, but should include supplies of electricity, gas and water, a sink, and possibly a fume cupboard.

(2) It may be desirable to have one or more benches fixed to the wall. The room could also contain movable tables of the same height. The tables could be rearranged among themselves or joined to the benches as required. Two might be joined end to end by a removable or hinged flap.

Such arrangements of furniture while suitable for physical and biological work are not suitable for Chemistry.

(3) The height of benches is a real difficulty. It seems that the best solution is to make them rather lower than is usual for Physics and Chemistry and rather higher than is usual for microscope work, with a corresponding adjustment in the height of the stools. The height of the pupils using the furniture should also be borne in mind.

(4) The problems of storage are likely to be acute in dual-purpose laboratories and need very detailed consideration. Adequate and convenient storage rooms are valuable but they do not solve the problem. There must be storage space in the room as well.

(5) The number of sinks required depends largely on the uses to which the laboratory will be put. A safe method would be to arrange the number of sinks to suit the subject which has the greatest need of them.

(6) In a general laboratory there is much to be said for supplying gas, water, and electricity to points along the walls, but the usual precautions for the isolation of electrical points from water and gas pipes must be observed. Additional supplies could also be picked up from covered wells under the floor, though some science masters strongly object to this arrangement. Temporary connections from gas or electrical points to distributing centres on benches or tables have proved effective in many schools.

North lighting, with the windows coming down to bench level and reinforced by top lighting is helpful for biology work, and at least one clear wall would be useful for simple experiments in mechanics.

(7) There should be provision for the use of films, lanterns, epidiascopes and wireless. For these reasons, if for no others, it might be sound policy to plead for a lecture room as well as laboratories in all schools, however small.

### 3. *Lecture Rooms*

Most teachers favour a lecture room, and prefer one large (double size) lecture room to two small ones ; this could be used for lectures, meetings of societies, etc., but might also be appropriate as a class room for other subjects. The effects of bad time-tabling are too often felt in the lecture room.

Some teachers have a definite objection to any lecture room at all, and would prefer the space so used to be incorporated in laboratories or in additional small rooms. A prime objection to the lecture room is that it forces the division of lessons into theory and practical, whether it happens to be convenient or not. It is said that the time taken to move material to a lecture room is wasted ; it cannot possibly be as well equipped for demonstrations as the laboratories themselves and usually those at the back can see little. Thus a number of science masters prefer a demonstration bench in the laboratory with benches arranged parallel to and facing it and windows at the side only.

#### THE DEMONSTRATION BENCH AND ITS EQUIPMENT

The demonstration bench should be as long as possible, 10 ft. at least, and 12 ft. and more if at all possible. A hinged flap or sliding panel may serve to increase the area temporarily. For demonstrations in the line of sight of the class a hinged flap at right angles to the bench top may be fitted. It should not be less than 2 ft. 6 in. in width. The top should overhang a few inches (say 2 in.) on the front and sides and rather more on the master's side. Knee space for sitting and toe space for standing are important.

The top should be of teak and the comments on the materials used in chemistry benches apply equally to the lecture room bench when it is used in part for chemical work. The underpart can be of pine, stained and varnished. The overall height of the bench should be 3 ft. Good clearance between the bench and the wall behind must be allowed.

If sunk gas taps are to be fitted, a 3-in. (or even 6-in.) wooden

*Notes on Figure 24.*

1. The doors of all cupboards open on both sides of the bench.
2. The knee space has been kept clear so that if preferred, the top can be arranged to be removable at this point.
3. Five nozzles are at the far side of the bench. Some masters prefer them to be horizontal, in which case they can be fixed on the bench-top or else mounted beneath the top and perhaps a hole cut for the tubing to pass through.
- Inclined or even vertical nozzles are recommended by other masters, the tubing passing through a suitable hole in the bench-top from a nozzle mounted beneath the bench-top.
4. One nozzle is shown on the near side with its tap. The other nozzles are controlled by taps from the near side.

Key to diagram :

- A.C.M.=A.C. mains voltage supply to two three-pin points, one being 15 amp. and one being 5 amp.  
 L.V.D.C.=Low Voltage (2-30 volts) Direct Current points. Each consists of a three-pin socket and two terminals wired in parallel and controlled by a switch.  
 L.V.A.C.=Low Voltage (6-16 volts) Alternating Current points. Each consists of a two-pin point and switch.  
 G.=Terminals wired invisibly to a Wall Galvanometer.  
 A.=Terminals wired invisibly to a Demonstration Ammeter.  
 V.=Terminals wired invisibly to a Demonstration Voltmeter.  
 T.=Gas tap controlling a nozzle on the far side of the bench.  
 T.N.=Gas tap and nozzle combined.

strip must be left between the underside of the bench and the top of drawers or cupboards.

*Drawers.* Some provision should be made on the master's side, possibly in two tiers as in Figure 24 ; such drawers should not be deep. Several subdivided drawers of 1 in., 1½ in., and 2 in. depth are useful. Two nests of varying overall depths, 2 in., 2 in., 3 in., 3 in., 5 in., 5 in., and 5½ in., have been found useful, the shallower drawers running in slots to economise space.

*Cupboards.* Two with shelves and one without shelves are suggested; these may run the full width of the bench and have doors which open on both sides.

A long cupboard with a door at the end is convenient for the storage of long apparatus ; advantage can be taken of the space behind the drawers if the drawers do not run the full width of the bench. Adequate space must be available to hold all the apparatus frequently used.

Opalite insets to hold bottles when needed have been suggested, but bottles are better not placed on the bench top, but on shelves at the side of the room, the acids being on shelves of plate glass or of wood covered with plate glass.

*Sink.* For Chemistry and Biology, an earthenware sink say 15 in. × 18 in. × 18 in. internally, must be fitted, either at the



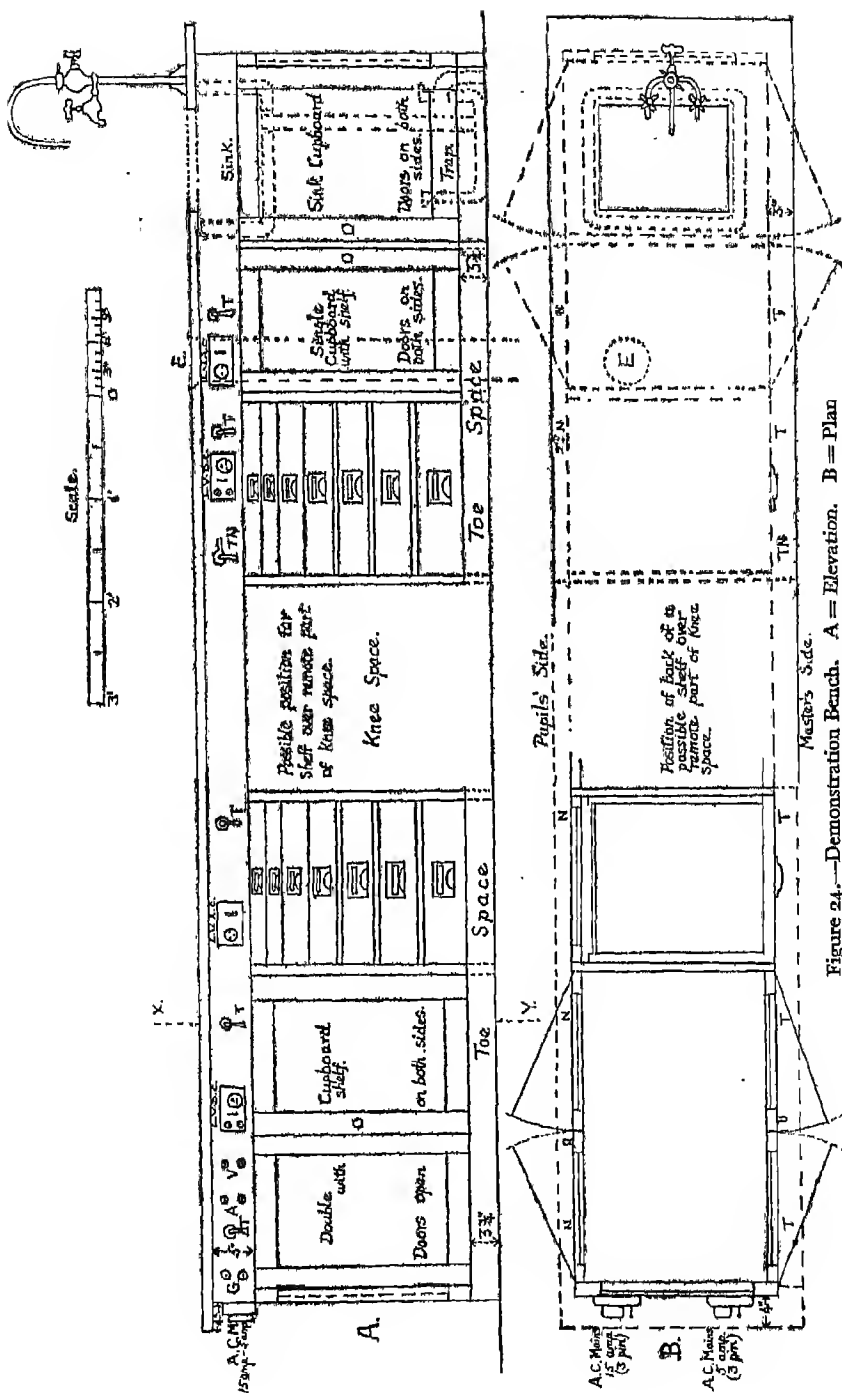


Figure 24.—Demonstration Bench. A = Elevation. B = Plan

end of the bench or sunk in the top with a loose cover and collapsible tap so that a flush surface is obtainable. A sunken sink takes up drawer or cupboard space beneath but is a neater job than one at the end of the bench. Trouble is occasionally experienced with the collapsible tap and if the sink is at the end of the bench the tap can be made to give the 22 in. clearance needed for such purposes as washing burettes.

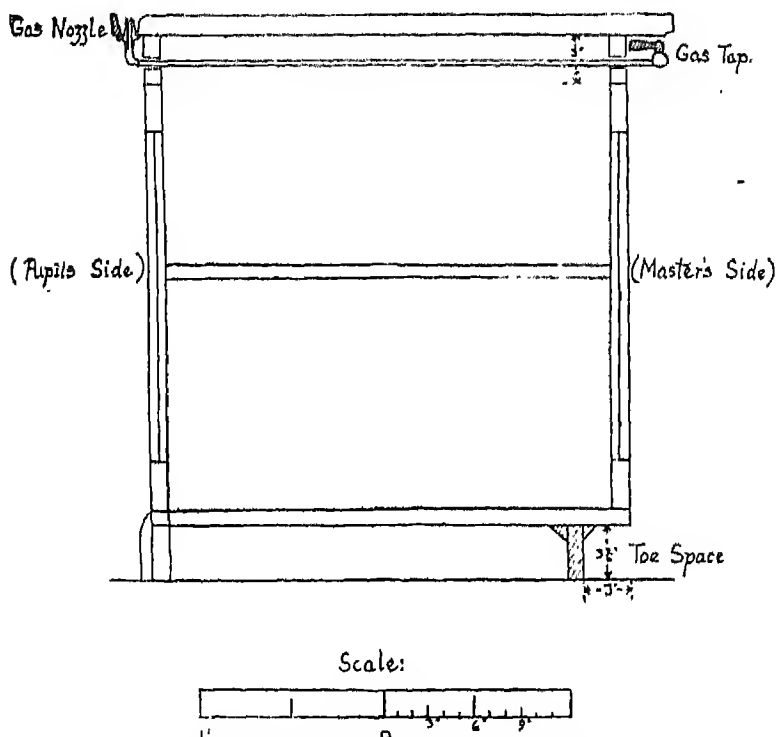


Figure 25.—Section of Bench Shown in Figure 24 (through X-Y)

The waste pipe should be of lead, discharging straight into a receiver or settling tank which can be fixed to deliver liquid into a channel beneath the floor. Material not affected by moisture can be stored in the bench near the receiver, e.g., gas-jars.

*Water Supply.* This is required at mains pressure and at least two taps are needed. Should mains pressure be excessive, it can be stopped down by adjusting the room stop (control) tap.

A very convenient arrangement is to have a gun metal swan-neck tap for use with long apparatus and to have two taps built on to this, one with a permanently attached all-metal filter-pump and the other to have a  $\frac{1}{4}$ -in. nozzle for the attachment of condenser tubing.

*Gas.* Ample provision of points (say one per 2 ft. of bench) is desirable to ensure flexibility, but they should be of a type to leave the top flush as burners are not required for every lesson. A convenient arrangement is to have the nozzles sunk below the

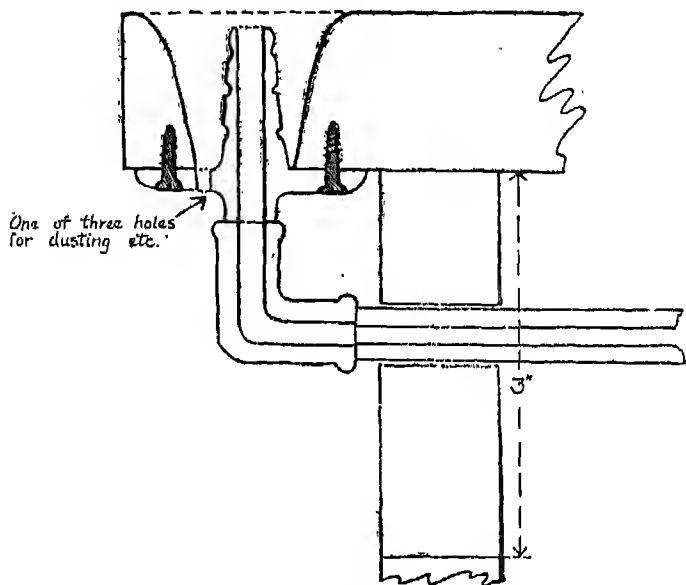


Figure 26.—Details of Sunken Gas Point

surface on the far side and to have the controls beneath the overlapping edge of the bench on the near side. (Figure 26.)

One  $\frac{1}{2}$ -in. gas supply point is useful.

The taps should be of gun-metal and for Physics no iron pipes must be used on the bench itself.

If water and gas taps are ordered direct from the makers they can be made to specified dimensions with a minimum of trouble and expense.

*Electricity.* Various types of supply are needed for an all-purpose bench; the fuses should be in the room and easily accessible.

- A.C. (1) One or two 15 amp. switch-sockets, one of which may be used for a lantern at the end of the bench. The leads behind (cab tyre) should be able to carry well over 15 amps.
- (2) One or two 5 amp. lighting switch-sockets.
- (3) A 6-14 voltage supply has also been suggested as convenient where possible.

D.C. at various voltage ranges has been suggested for electrolysis, etc. The ranges suggested vary from 2 to 30 volts : voltages above 70 may be used for arcs. Difficulties of charging must be considered in this connection.

*Exhaust Draught.* Where possible this is to be recommended in addition to the provision of a fume cupboard. A suitable installation included the provision of two holes in the bench top, about 5 in. in diameter, with loose flush lids, communicating with an asbestos-composition duct leading to a fan and chimney. Experience shows that an injector type of exhaust is unnecessary.

In connection with this, all-glass hoods, which stand when in use over these holes, are a great improvement on a fume cupboard. Such hoods need not be large enough to cover the whole apparatus, but only the end from which gas is evolved. For some experiments proximity to the hole is alone required. The hood consists of three rectangles of glass (about 15 in. high  $\times$  12 in. wide) hinged with gummed tape so as to open out into three vertical slides of a rectangular prism, together with a separate rather larger square of glass to form the top of the prism.

#### OTHER SUGGESTED FITTINGS AND ATTACHMENTS

- (1) On occasion an asbestos sheet on fly-back hinges fitted on the wall, e.g., behind the blackboard, to increase distance from the class for experiments which may involve explosions.
- (2) Sunk glass-fronted trough with fitted wooden top at the centre of the far side of the bench for use as a pneumatic trough. It should be painted dark inside.
- (3) Terminals connected by *very well insulated* cables to a galvanometer supported on a stone corbel, say 8 ft. above the floor in a corner of the room behind the demonstration bench. Alternatively, four leads from four terminals might be connected to an ammeter and

voltmeter with large 10-in. faces mounted on the wall behind and above the bench. Shunts, bobbins, etc., can be operated on the bench top. Instruments, which have large figures, are very suitable. Allowance should be made for the resistance of the connecting leads which run down the bench under the floor and up the wall to the demonstration instruments.

- (4) The ceiling above the bench to be provided with wooden beams as long as the bench top, for suspension purposes.
- (5) A flat board on the wall, fixed 4 in. from it, is useful for the attachment of instruments, clocks, diagrams.
- (6) Where height allows, a diagram screen of laths and upholsterers' wide tape can be suspended from pulleys fixed to a board on the wall above the bench. The laths can be fitted with bull-dog clips to hold papers.

The following suggestions are not likely to receive universal approval since their use would be occasional :—

- (7) A ripple-tank sunk in the bench top with a cover or lid.
- (8) A lantern with prism reflector for giving an image on a screen above the blackboard.
- (9) On the wall behind the bench a vertical white board with equipment for ray projection.

#### POSITION OF FUME CUPBOARD

The majority prefer this to be situated behind the demonstration bench, either to one side (right) of the blackboard, or behind it. A good arrangement is to have a fume cupboard fitted in the wall between two rooms and with two sliding doors on the lecture-room side, an inner glazed door of the usual type, and an outer sliding door which is also a sliding blackboard. If a preparation room or another laboratory adjoins the lecture room the same cupboard can serve both rooms or at least be accessible from both sides.

An effective method is to have a separate fume cupboard of special shape to one side of the demonstration bench, sufficient space being left between for a trolley with epidiascope to be wheeled up as required. The door and controls are on the master's side, there is a light over the fume cupboard and a direct exhaust through to the ceiling. Storage space beneath is open to the

class, except in so far as room is taken up by the sink and its receiver.

Forced draught is essential and the provision of electric light directly above the glazed roof will allow of sufficient illumination to enable details of apparatus to be seen from the distance which will separate the cupboard from the pupils' benches.

Where such provision can be made, the use of draught holes on the demonstration bench itself, as mentioned in the paragraph on Exhaust Draughts, is possibly more desirable than a separate fume-cupboard.

#### DESKS FOR PUPILS

- (1) All pupils must be able easily to look down on the surface of the demonstration bench. This is secured if the seating accommodation is arranged on tiers which may be about 3 ft. wide, rising by 8 in. steps. Shallower steps may be used in the lower stages. The lowest row should not be on the actual floor of the room.
- (2) The upper surface of desks should be adequately sloped to give comfort in writing and may be fitted with a flat portion with pencil groove and a wooden edging to prevent things falling off forwards.

Lockers are undesirable as they accumulate rubbish, but a small shelf (open in front for inspection purposes) beneath the top will serve to accommodate books not actually in use.

Single desks are probably best if space permits. Otherwise longer benches may have to serve, but these should have "dished" seats with backs and be hinged in sections to facilitate entry. The use of separate chairs with individual desks gives the most comfortable accommodation.

- (3) For a chemistry lecture room, the nearest bench must not be too close, but given at least five feet of clearance.
- (4) A gangway down each side is desirable and if possible one down the middle as well.

Figure 27 shows a layout for a lecture room which has proved satisfactory, though the room has actually been adapted to its present purpose.

#### 4. *Preparation Room : Store Room*

Probably the most suitable position for the preparation room and store is immediately adjoining the laboratory, behind the

demonstration bench and blackboard. Each room opens into the other and into the laboratory. For Biology, a large preparation room is not so much needed as a large store. In the chemistry laboratory it is useful to have a fume cupboard behind the

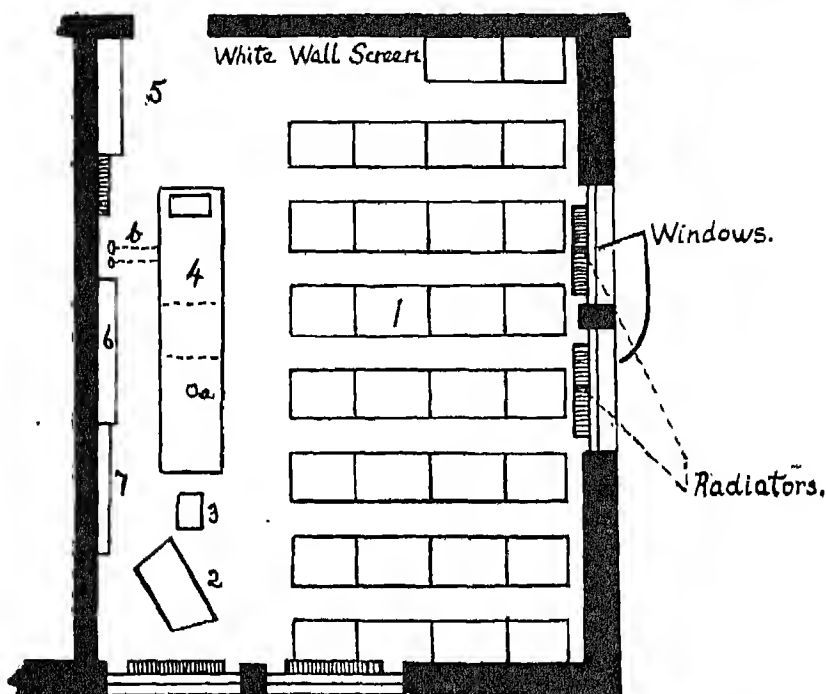


Figure 27.—A Class Room Adapted as Lecture Room

This design was adapted to suit room already built. The windows facing the teacher are a serious objection—not by keeping the blinds on these windows partly down.

Detail :—

- (1) Individual desks on Raised Tiers
- (2) Cupboard 4 ft. front facing class. 3 in. Sliding sash on reverse side. Gas taps and Water taps in cupboard. Controls outside. Cupboards underneath for storage.
- (3) Epidiascope trolley on wheels for moving to convenient place.
- (4) Lecture Bench—with removable section in centre, sink and taps; forced draught outlet (a). Four gas taps under overlapping top (one tap  $\frac{1}{4}$  in.). Also protected by overlaps :—  
2 points 12 volts A.C. 2 points 12 volts D.C. 2 points 230 volts A.C.  
Space under bench, apart from middle portion, which has removable shelf, taken up by cupboard and drawers, some shallow. Receiver placed in one cupboard.  
(b) Leads from Bench under floor to demonstration ammeter and voltmeter mounted on wall at height of 7 in.
- (5) Wall shelf with cupboards under.  
Fuse Boards for 12 volt D.C. and 230 volts A.C. fixed to wall at accessible height over item 5. Board about 1 in.  $\times$  1 ft. at height of 6 ft. from floor and 4 in. from wall fixed along wall from corner over item 5 to edge of blackboard. Used for mounting occasional apparatus, e.g. pulley experiment or stop clock.
- (6) Double sliding blackboard. Roll up white screen. Mains electric plug on pier in opposite window space.
- (7) Wall bottle shelves, some glass covered. All windows fitted with dark blinds. Ventilation of darkened room assisted by special arrangement of blinds (see appropriate section) and mechanical extraction of air through outlet in items 4a and 2.

blackboard, available in both laboratory and preparation room and serving as a hatch between them.

The preparation room makes a useful private room for the science master, where he may keep his own special apparatus and carry out experiments of his own. A special staff room is only possible in large schools ; it may prove useful for consultations amongst the science staff, but may tend to segregate them from their colleagues.

The preparation room will often serve as a workshop. No separate workshop is needed if the room contains a bench fitted for the repair of apparatus, glass-blowing, etc., and if the school possesses a general workshop suitable for wood and metal-work. There should therefore be a good bench, running the length of the room, and supplied with gas, water and electricity ; cupboards and drawers below, shelves above. For Physics there should be a vice on the bench and tool rack above : for Chemistry a complete set of reagents.

The preparation room may also, especially in smaller schools, have to serve as a store room. In any case, the more expensive apparatus and chemicals may be kept here. The poison cupboard—fitted with a special lock, the key of which ought never to leave the master's possession—should be in the preparation room rather than in the store.

Boys, with the possible exception of members of the sixth form, should not be allowed in the preparation room under any circumstances.

### WORKSHOP EQUIPMENT

The following note on the equipment of a laboratory workshop has been sent to us by a correspondent.

In addition to the usual hand tools to be found in the average workshop, there are now available excellent small machine tools which are ideal for the school workshop.

Except in the more fortunate schools, a skilled instrument maker is not available and generally youths with little or no training have to be employed. To train a youth to be a craftsman is a long process. It is a tedious job to train a boy to drill a hole straight with a hand drill, but provide him with a drilling machine and the difficulty is overcome immediately. This applies equally to other operations such as sawing and planing. With their help, any intelligent youth can turn out first-class work



with little training, the cost of the machines being easily repaid in a single year. With a suitable equipment of these machines, repetition work may be undertaken on a profitable basis; an intelligent use of the machines combined with a good design will enable apparatus to be made which is at least equal in quality to the professional article and with the added advantage of using one's own design.

Small power-driven machine tools, such as drilling machines, circular saws, band saws, jig saws, planing machines, sanding machines, and shaping machines used to be readily available at an average price of £10 each. Lathes have not been included in the above list as the above tools are of American manufacture; lathes are in plentiful variety.

### 5. *Other Special Rooms*

It is valuable to have a number of small rooms, not definitely allocated, but used for various purposes at the discretion of the science master. Such rooms may contain books and serve for calculations, writing, or reading: special experiments may be left set up in them for senior pupils: they may house bulky apparatus for which there is no room elsewhere, and in many other ways prove of value. It is desirable, however, on account of definite fittings and services required, that a dark room and a greenhouse should be provided.

A dark room is necessary for photographic work. The walls and ceilings should be dead black and very special attention should be paid to ventilation. There is generally difficulty over ventilation because of the light leakage which frequently accompanies it.

An excellent method of overcoming the difficulty is to have a permanently open doorway as shown in Figure 28.

All the walls and ceilings around A should be coloured dead black—with a roughened surface.

Another method which is more expensive but has advantages of better ventilation and easier movement in carrying articles into the room, is to arrange either a revolving wall or a revolving inner part on the principle common to rotating doors. (Figure 29.)

On the whole, the open doorway arrangement seems to be the better.

A labyrinth arrangement has also proved to be convenient if the walls are dead black. In this case again, it is better to do

without a door. If more than one compartment is being used simultaneously, adequate passage space is necessary. (Figure 30.)

A room for optics should always be long. Photographic rooms may be of any shape or size provided they are not too small for easy movement.

Only in exceptional circumstances should the same dark room

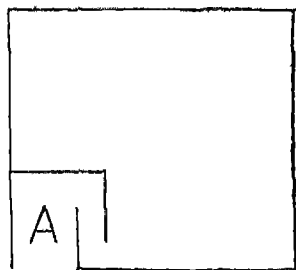


Figure 28.—Ventilation of Dark Room

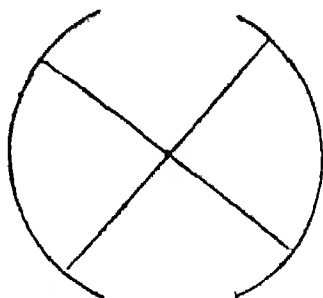


Figure 29.—Another Method of Ventilating Dark Room

be devoted to photographic purposes and to advanced optical work. Adjoining dark rooms, one for photography and one for optics, are particularly convenient.

Gas and electricity should be laid on and there should be a shallow sink (6 in.  $\times$  8 in. deep) with teak grid for developing

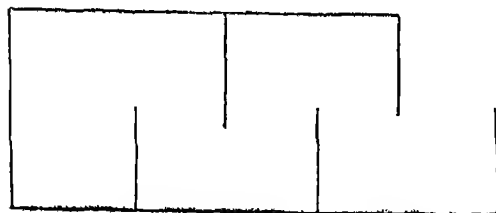


Figure 30.—Labyrinth Arrangement for Dark Room

dishes. Shelves for developers, "hypo," and chemicals best kept in the dark, are useful additions as are also shallow drawers.

A greenhouse—or, in default, a Wardian case—should be attached to the laboratory wherever Biology is taught as a full subject.

A suitable size is 12 ft.  $\times$  8 ft., 8 ft. high at the ridge and 4 ft. at the eaves. It may, of course, be larger if required. If the greenhouse is built on to the laboratory, the same heating apparatus will serve both, otherwise an upright boiler is necessary. The

greenhouse should open from the laboratory and should be supplied with water, and have at least one water tank suitable for aquatic life.

It should be a brick structure, with a concrete floor, a span roof (not a lean-to) being desirable, and glazed with 21-oz. glass. There should be adequate ventilation. Staging should be provided on each side of a central gangway.

#### LIBRARY

The Science Library should form a section of the school library, text-books and works of reference being kept in the laboratory. These should include tables of logarithms and trigonometrical ratios, books of physical constants, periodicals, *Nature*, *The School Science Review* ; text-books on chemical analysis and on biological technique as well as works on practical physics ; floras and other books for the identification of living things ; books on birds' eggs, insects, minerals, and perhaps fossils ; also text-books larger and more systematic than those in class use. In elementary or general science laboratories, it has been found stimulating to have a shelf or two of small, well-illustrated, and interestingly-written books on miscellaneous science subjects, the wider the range the better. Boys with a few odd minutes to spare at the end of a double period may well be encouraged to browse amongst these, and so add to their interests.

#### MUSEUM

There is no need for a special science museum, separate from the school museum. It is, however, useful to have a wall case, either just inside the laboratory or lecture room or (better) just outside the door leading to it : in this can be exhibited from time to time relevant specimens borrowed temporarily from the general museum.

## CHAPTER IV

### APPARATUS AND ITS MAINTENANCE

The difficulties of attempting to give advice to teachers on the choice of apparatus for use in their laboratories are considerable, and it is with the greatest diffidence that this task has been approached. The teacher contemplating the purchase of material will find a large selection listed by different makers, and until he and his classes have used them, he has no real idea of their value. He should add to his apparatus only according to his needs and experience; many laboratories have their shelves choked with useless apparatus.

In considering the stocking of his laboratory, whether it be a new one, or one already in working order and merely needing replacements, the teacher must bear in mind that he is planning for his successors as well as for himself. He should have very definite ideas as to the aim and scope of his practical work, and should envisage a definite system into which his new supplies must fit. He must consider whether his practical work is to be mainly class work or demonstration; his decision on this point may depend again on the time allotted for his subject, on the type of pupil, and on whether the pupils' main interests are to be in Science or not. He must consider his spending allowance, the size of his laboratory, the storage accommodation, his own bias, his mechanical ability, whether he has the services of an assistant or not, and the presence or absence of a workshop. All that can be done here is to give a certain amount of "stock" advice to the beginner which may prevent him from making serious mistakes, and help him to find his own line of action.

One major question he must face, and face at once, is the relative amounts of practical work to be done by the boys and by himself as a demonstration. We are not alluding here to such demonstration experiments as may well form part of a lecture course or theoretical lesson—such as the manufacture of sulphuric acid, colour experiments with a lantern, and sound experiments with organ pipes, but to those routine experiments which constitute

the main body of the course and which make it "experimental science."

There is sometimes a tendency, more especially on the part of inspectors and headmasters, to stress the importance of demonstration work at the expense of class work, owing partly perhaps to its smaller cost, and partly to some saving of time in an overcrowded timetable, because in this way larger forms can be "taught" at one time. Some teachers are born demonstrators and enjoy the work, and with them an occasional demonstration lesson, in which boys see an experiment skilfully carried out, may prove an inspiration; others find the preparation and setting out of apparatus for experimental work by a class takes more time than they can afford. In the great majority of cases, however, we believe that the pupil himself should do the utmost amount of practical work possible within the range of his own experimental skill and the resources of the laboratory in which he works.

The question goes to the root of the whole object of science teaching, which is surely to make the boy *understand*. Until he has done the job himself, however clumsily and inaccurately, until he has handled the apparatus, until he appreciates the unlimited possibilities of error and the repetition and checking necessary to detect the error, he has learned no real science.

Thus the teacher is well advised to allow the pupils to do for themselves, either singly, or in pairs, the largest amount of experimental work possible. Even when the nature of the experiment is such that apparatus is available for only two or four boys, it is possible to arrange experiments in a "rota" and have a class doing six or eight different experiments at the same time, with all doing each experiment in turn. Another method which has been tried for some years with success is to allot a term in the School Certificate year for the more advanced experiments, say, in heat—those in which careful measurement is essential. In the first half, experiments are done on calorimetry, melting- and boiling-points, and so on, for which apparatus is available for everyone at one time, and theoretical lessons are given on other subjects, such as expansion and vapour pressure. The last half of the term is occupied with experiments on this work, one pair of boys doing expansion of gases, another pair vapour pressure of a liquid, and so on; having already covered the theory they can work without much explanation at the time. This procedure is repeated in the following term in Light and Sound.

Too much should not be expected of the pupil in the way of accurate results. Skilled experimental work needs much training and continual repetition of the same experiment, which is impossible if only from lack of time. Careful work should be insisted on, a reasonable standard of accuracy expected, and sources of error and their elimination understood.

Complicated apparatus should be avoided, and so should the "composite" apparatus which will do for half-a-dozen experiments; as a rule, the result is confusion in the boy's mind. One piece of apparatus for each experiment is a sound working rule.

A modern tendency in the physics laboratory is to use larger quantities for experiments, e.g., in specific heat or on the Principle of Archimedes, so that spring balances or letter balances can be used for weighing instead of chemical balances; a considerable saving of time is thus claimed. It is perhaps too early yet to make a definite decision on this matter, but the boy who is going to take up Science seriously will have to learn to weigh accurately, and should be taught to use the chemical balance as soon as he is able to appreciate its value. Riders (1 g.) for "fractions" are useful, saving time and the loss of small weights. Some firms market a chain-drum attachment which quickly gives fractional weights. If proper attention is given to the number of significant figures which may reasonably be expected in a measurement (e.g., in calorimetry), much needless "accuracy" in weighing—and consequent loss of time—may be avoided.

### QUALITY

The quality of apparatus is important; the pupil should have the best apparatus he is capable of using. He should be told this, and careful usage insisted upon. Cheap glass and porcelain lead to excessive breakages and make the pupil careless. The use of cheap glass may be more expensive in the long run than Monax or Chance's resistance glass; Pyrex withstands temperature changes so that no gauze is needed. Similarly, Worcester, Sillax, and Berlin porcelain are all to be recommended—and it pays to use stainless steel for rules (wooden rules warp), and Staybrite for stands; also stainless steel dissecting instruments.

The same holds good for other apparatus. Mirrors and lenses that will not give a clear image are worse than useless; micro-meters (on expansion apparatus) that fall to pieces when touched

demoralise the experimenter. If money is restricted, buy less apparatus, but take care that what you buy is good.

### QUANTITY

This should be carefully considered. For apparatus which will keep, such as beakers and crucibles, there is often considerable reduction in buying by the dozen, or even by the gross. In order to take advantage of this, several years' stock should be ordered at one time. Similarly, rubber tubing may be ordered 60 ft. at a time, glass tubing in 7 lb. lots, electrical wires by the lb., and so on. Some kinds of glass, however, are liable to deteriorate on keeping.

### CHEMICALS

For many purposes the "commercial" grade is useless; "pure" is required, and "puriss." for analytical work. "A.R." chemicals for sixth form work are necessary. Some few chemicals are required in bulk—the ordinary bench reagents, granulated zinc, caustic and washing soda, alum, ammonium chloride, chalk, marble chips, saltpetre, common salt and copper sulphate. They should be ordered in 7 lb. lots or more. Acids and ammonia should also be ordered in bulk; the reduction in price is considerable and much trouble over carriage is saved, though in some cases road delivery solves this problem. Substances required only for qualitative analysis should be ordered in much smaller quantities—it is not uncommon to find a laboratory seriously overstocked in this respect.

Dangerous chemicals like sodium, phosphorus, and bromine, expensive substances such as silver nitrate, iodine, mercury salts, potassium iodide, salts of arsenic, alkaloids, ether, chloroform, and absolute alcohol, should, of course, be kept in a private cupboard in the preparation room under lock and key. It is advisable to keep an eye on the supplies of chemicals so as to order fresh supplies before the stock in hand is exhausted.

### SIZE

The teacher will do well to go carefully into the matter of sizes. When ordering flasks it may be wise to order at the same time rubber stoppers to fit them. Many teachers find that much trouble and time are saved by having flasks, tubing, and other

requirements of certain standard sizes. Similarly, a standard diameter for mirrors and lenses is convenient since one set of holders can then be used. Many porcelain boats supplied do not fit the smaller standard sizes of hard glass tubing.

### NUMBERING

All individual apparatus belonging to sets should be numbered for identification purposes and for checking the measurements made by pupils, e.g., lenses, mirrors, thermometers, boxes of weights, magnets, resistance coils: where constants (focal lengths, etc.) are known, these should be catalogued. Glassware can be scratched with carborundum; small gummed labels may be used, or marks of distinctive colour may be painted on pieces of apparatus which should be stored together.

Certain articles seem to offer great temptation to boys and tend to disappear rather frequently; for these regular and careful checking is needed. They include small compass needles, magnets, convex lenses, copper wire, test-tube holders, rubber tubing, springs, burette clips, not to mention mercury, sodium, and phosphorus, which should be kept under personal control.

### CLEANING

A regular overhaul of some apparatus is advisable. Iron stands require an annual coat of aluminium paint, Berlin black, black stove enamel, or Brunswick black; a weekly run over with a slightly oily rag helps to prevent rusting. Tarnished or corroded brassware can be cleaned with a liquid consisting of concentrated hydrochloric acid containing as much oxalic acid as it will dissolve. Screws (e.g., of clamps) need an occasional oiling, or greasing with tallow.

Ordinary check dusters or "glass cloths" are advisable for polishing glassware, but if carefully rinsed with water after use it seldom needs drying.

For lenses and mirrors "cleaning tissue" is recommended, the material being thrown away after use.

Useful cleaners for benches, etc., are sponge cloths (bound edge essential), absorbent cotton, cotton waste (bought in bulk and thrown away after use), rubber squeegees and "scourer" cloth suitably cut up. Swabs or sponge cloths should hang under the bench.



### TAPS, STOPPERS

Taps of burettes or separating funnels should be lightly smeared with a special tap-grease; as they are easily mixed up they should be tied to the apparatus by thread—rubber bands perish. The science master will save himself much time and material by exercising reasonable care over glass stoppers of bottles. A slight greasing is suitable in many cases, or the stopper may be surrounded with a ring of paper or thin rubber before insertion; rubber bungs are recommended for sodium hydroxide solutions.

### LABELS

Opinion as to the best type of label is fairly equally divided between the gummed paper label, covered with paraffin wax, or celluloid in amyl acetate, and the sand blast type. One science staff finds Nadir tape very satisfactory—it is acid- and fume-resisting.

### *Individual Sets for Class Use*

The schedules of apparatus which follow are intended as suggestions for the preliminary stocking of a laboratory. This minimum of apparatus will allow the work to go forward, so that as the teacher develops his own syllabuses he can add to it to suit his needs. The first list deals with the laboratories in which boys work individually or in twos. The later sections contain a short list of apparatus too expensive or too cumbersome to be issued to members of a class but useful for sixth form work and for demonstration purposes, or for larger groups of pupils.

Certain articles are needed for frequent use in elementary work, and are thus required in sufficient numbers to provide each pair of pupils in a full form, or each member of a half-form, with a complete set. It may be noted here that glassware is often unnecessary in physical work; metal vessels (calorimeters, tins) can often be used instead of beakers, and paste pots or jam jars will serve in biological work where heating is rarely required; tin boilers may replace flasks for raising steam. A short list of such apparatus, with suggested types and sizes, and occasional comments, is as follows :—

### GENERAL PHYSICS

Metre and half-metre rules—preferably marked also in inches and tenths.

Measuring cylinders—100 c.c. (by 1 c.c.), 200 c.c., and 500 c.c.

Density bottles—25 c.c. or 50 c.c.

U-tubes, Hare's tubes—50 cm. leg.

Boyle's Law tubes (glass only); barometer tubes—not so narrow that mercury cannot be poured down them.

Retort stands—large (24 or 30 in. high) with good bases, three rings (to fit flasks), clamps, and bosses to take smaller as well as wider articles. Stainless steel may be recommended for physics and biology laboratories.

Tripods, triangular, of suitable height to use with the bunsen burners—not less than 8 in.

Bridge and glass jar for weighing immersed solids.

## MECHANICS

Inclined plane and brass roller.

Single pulleys (3), double (2), made of aluminium or bakelite.

Spring balances (3), e.g., up to 1 kg. or to 7 lb., or a "light" set in metric weights and a heavier set in lb. For general purposes 8 lb. by  $\frac{1}{2}$  lb. and 3 kg. by 1/10 kg. (tubular) will serve.

Set of iron weights, with rings, 100, 200 (2), 500, and 1,000 gm.

Set of 2 cm. cubes of various materials for density experiments.

*Note.* Sets of apparatus are very useful and very efficient, but usually rather expensive.

Balance as for Chemistry, but should read up to 250 gm. at least.

## HEAT

Calorimeters—copper or aluminium, 3 in.  $\times$  2 in.—and outer jackets, steam heaters for specific heats. Metals in small pieces for specific heat experiments. Cans for supply of steam, steam traps with rubber stoppers.

Thermometers, engraved stem,  $-10^{\circ}$  C. to  $+110^{\circ}$  C. by  $1^{\circ}$  C.; also some of the same range by  $\frac{1}{2}^{\circ}$  C. and others of high range ( $200^{\circ}$  C.). Leslie's cubes, iron balls as sources of radiation, rods of copper, brass, iron, etc., for conductivity experiments. Heat-sensitive paper.

## LIGHT

Plane strip mirrors (2),  $1\frac{1}{2}$  in.  $\times$  6 in.; large pins, protractors. Glass blocks ( $4 \times 2 \times 1$  in.); prisms—equilateral, some with  $30^{\circ}$ , others with  $45^{\circ}$ ,  $45^{\circ}$ ,  $90^{\circ}$ , of large size (at least  $1\frac{1}{2}$  in. or 2 in.

edge), and good quality flint glass. Some source of a beam of light is desirable and is considered essential by most teachers.

Concave and convex mirrors and lenses—at least 3 convex lenses for each pupil, of different focal lengths, say 10, 5,  $2\frac{1}{2}$  in. All lenses (except short focal length) and mirrors to be of the same diameter, say  $1\frac{1}{2}$  in. or 2 in. For concave mirrors, dentist's mirrors are useful.

As lens holders, large corks with V-grooves are satisfactory. Screens, cross-wire screens, screens with slits for spectrum experiments, coloured glasses, coloured paper, and gelatine filters (S.M.A. Modern Science Memoirs, 13).

### SOUND

There are few really useful experiments in sound which can be performed simultaneously by all the members of a class, working in pairs. A set of tuning forks, between C and C' may, however, be useful and sometimes can be made.

### ELECTRICITY

Magnets—tungsten or cobalt steel, 6 in. or 8 in., in pairs in boxes.

For magnetometer experiments and plotting magnetic fields, the science master might find it worth while to try magnets made of the new magnetic alloys, such as "alni" and "alnico." These are much more powerful than the ordinary magnets of the same volume: it is even claimed that with reasonable care they may be used as magnetic standards.

Magnetic needles,  $1\frac{1}{2}$  in. or 3 in., on stands; small watch compasses (at least 2 per pair of pupils).

Steel knitting needles, soft iron bars  $\frac{1}{2}$  in. by  $\frac{1}{8}$  in. (six per pair of pupils).

Glass and ebonite rods and rubbers (silk and fur). For simple electrostatics experiments, a flat ebonite rod pivoted on a needle is useful.

Most electrical apparatus is relatively expensive, so that a rota system has usually to be arranged or the group system adopted. Recommendations will, therefore, be found in the section on Group Sets.

### ODDMENTS

The smooth running of a laboratory often depends to a considerable extent upon the supply of a number of "oddmments."

These include such things as string and thread, sealing wax and soft red wax, needles and pins, drawing pins (good quality), sandpaper, pliers, screwdrivers, rubber bands, gummed paper and labels, matches, squared paper, white cardboard, scissors, corks, aluminium paint, white and dead black paint, iron wire, cotton wool. Mention may also be made of the many uses of modelling wax in a laboratory. These include filling up holes round tubes or wires, supporting a magnetized needle or plumb line from the edge of the bench, and so on.

Small tins which have contained cigarettes, pastilles, etc., are very useful as containers, so are pill boxes (useful as scale pans) to be obtained from a chemist. And above all, wide-necked glass bottles. Much labelling is saved if pill boxes with glass lids are employed.

### CHEMISTRY

Test tubes 5 in. or 6 in.  $\times$   $\frac{5}{8}$  in. or 6 in.  $\times$   $\frac{3}{4}$  in. are useful sizes, with 3 in.  $\times$   $\frac{3}{8}$  in. for experiments in which the tubes are destroyed: boiling tubes 6 in.  $\times$  1 in.; test tube racks with pegs, funnel (3 in.), brush. Hard glass test tubes.

Beakers, 150 c.c. (tall), 250 c.c. (squat)—up to 350 c.c. or even 500 c.c.

Flasks—150 and 350 c.c.—perhaps six of 500–1000 c.c. per class. Watch glasses ( $2\frac{1}{4}$  in.), clock glasses (4 in.). Glass crystallising dishes (6 or 8 cm.).

Distilling flasks, useful also for boiling-point experiments, 50 or 100 c.c.

Gas jars (or hydrometer jars), 8 in.  $\times$   $1\frac{1}{2}$  in. or 10 in.  $\times$  2 in. and covers.

Pneumatic trough—glass or earthenware; beehive shelf—shallow ( $1\frac{1}{2}$  in.).

Deflagrating spoons, tapers, splints.

Calcium chloride tubes—straight or U-form (6 in.).

Glass tubing, say 5–6 mm. external diameter.

Combustion tubing, say 10 in.  $\times$   $\frac{5}{8}$  in.: tube furnace to fit bunsen and porcelain boat.

Porcelain crucibles and lids, 4 or  $4\frac{1}{2}$  cm. diameter.

Porcelain evaporating dishes—6 or 8 cm., but resistance glass is useful for many purposes.

Crucible tongs—nickel or gunmetal, 6 in.

Pipe-clay triangles to fit crucibles (and tripods), say  $2\frac{1}{2}$  in. side; wire gauze 6 in. square, 20 meshes to the inch.

Blowpipes and charcoal blocks (3 in.  $\times$  1 in.  $\times$  1 in.).

Indiarubber tubing ; 5 or 6 mm. for connections, 11 mm. for bunsens. Mohr clips.

Filter papers, 11 or 12½ cm. diameter.

Bottles for principal reagents—sand-blast labels with large letters are best ; usual sizes are 270 c.c. or 350 c.c., but it is not necessary to keep them *full*—the more they contain the more a pupil will use, in spite of instructions. It is useful to number bottles (with a glazier's diamond), so that they can be kept on each bench in an agreed order.

Volumetric analysis ; for this graduated flasks are needed 100 and 250 c.c., with some of 500 and 1,000 c.c. Pipettes—10, 20, 25 c.c.—and a few 50 c.c. and 5 c.c. Burettes—with taps—50 c.c.  $\times$  1/10 c.c. Conical flasks (250 and 500 c.c.) and white tiles for titration.

Graduated glassware suitable for school work should be calibrated in ml. (rather than c.c.), and at 20° C. in accordance with the recommendation of the British Standards Association. "Student" quality will not serve for many requirements, and it is worth while to obtain British Graduated glassware, accuracy equal to standard Class B, but unstamped ; the increase in price is not very great.

The following will need to be available generally, though in most cases there cannot be one to each pair of pupils :—

Condensers.

Victor Meyer vapour density apparatus ; apparatus for depression of freezing-point and elevation of boiling-point.

Kipp's or other gas generators.

Also many articles such as desiccators, filter pumps, pestles and mortars, separating and dropping funnels and cork borers and files.

## BALANCES

For chemical work a satisfactory balance can be obtained at a reasonable price, weighing up to 250 gm. and sensitive to 10 mg. ; a case is desirable. Balances of better quality are advisable for advanced pupils : these should have longer beams. Beams of light aluminium alloy are not recommended for ordinary school work. Bakelite pans are preferable to brass, which corrodes.

Weights should be in boxes ; if smaller weights are used they

should be standard shapes ; 0.5, 0.2, and 0.1 concave fractions are easier to handle. Some masters prefer riders instead of decimals of a gram ; a Grace's attachment serves the same purpose.

### BUNSEN BURNERS

The cost of these varies according to quality and diameter of tube : a substantially made burner is desirable. Some may prefer Marshall's, which dispenses with the central gas jet. Higher temperatures can be obtained with the Teclu (cone and disc for regulating air and gas) and the Mcker (having a nickel lattice at the top of the tube).

### BIOLOGY

A dissecting set, consisting of :—

- 2 pairs of scissors, 2 scalpels.
- 1 flat razor or several razor blades with holder.
- 1 pocket lens (triple) or watchmaker's eyeglass with aluminium setting.
- 2 mounted needles.
- 1 fine camel hair brush.
- 1 or 2 pairs of forceps, stainless steel.
- 3 glass slips and some  $\frac{1}{4}$  in. diameter circular cover glasses, and a piece of pith.

Many scissors and scalpels sold are nearly useless : all scissors should have straight shanks and all scalpels should be sharply pointed. A tenotomy knife costs a shilling more than an ordinary scalpel and is well worth while.

Other requirements : test tubes, watch glasses, beakers, funnels, crucibles, graduated cylinder, gas jar and cover, glass jam jars, Bunsen burner, filter stand, adjustable wood holder stand, black and white tile, dissecting dish and board, thermometers, thermos flask, simple potometer and osmometer.

### MICROSCOPES

A dissecting microscope for School Certificate forms, one per pupil if possible, and/or a nature study microscope.

For individual sixth form work, general purpose microscope objectives 3 and 7 ; double nose-piece ; eye-pieces 3 and 5 (with pointer).

Demonstration microscope with double nose-piece, three objectives ( $\frac{2}{3}$  in.,  $\frac{1}{8}$  in.,  $\frac{1}{12}$  in. oil immersion), two eye-pieces with pointer, condenser, iris diaphragm, mechanical stage, bull's eye stand condenser for opaque work. Magnification up to 1,200 or 1,500.

Micro-lamp, with opening on the side, since the name of modern bulbs is stamped on the end.

### *Group Sets*

In laboratories with a limited supply of apparatus, pupils may occasionally work in groups of four or even more. This is not to be recommended, and should be allowed only when other arrangements are impossible. In cases where each pupil in turn may make an adjustment and measurement, it will serve; and the following suggestions are made of apparatus and experiments suitable for such groups. These experiments can often be arranged in a rota so that pupils work in pairs, but only one or two pairs are doing the same experiment at the same time. The same holds good for much of the demonstration apparatus in the next section.

- (1) Parallelogram of forces. Pulleys, inclined plane, etc.  
Determination of "g."
- (2) Gas Laws. Coefficient of Linear Expansion, Absolute Expansion of Liquid. Vapour Pressure. Hygrometers. Radiation: thermopile experiments.
- (3) Experiments with spectrometer, optical bench, photometer.
- (4) Sonometer, resonance column; frequency of a tuning fork (using gramophone turntable).
- (5) Electrical experiments generally.

Magnetometers (deflection)—tee form with detachable scales is useful for storage; a combined magnetometer and tangent galvanometer should be avoided.

For elementary work in electricity, a set may include accumulator, Daniell Cell, Tangent Galvanometer, sensitive galvanometer, rheostat, resistance coils (2–20 ohms), Wheatstone bridge and potentiometer (half metre length is quite satisfactory). Electrodes—platinum with copper leads in glass tube—for electrolysis in test tubes.

Accumulators: those with hydrometers are recommended;

the block type is good. 30 or 40 amp.-hrs. capacity is a minimum. For safety, see every circuit before connection is made to the accumulator. Some users say that NIFE accumulators are very handy for class use.

Rheostats : the slate form, feet mounted on wood, is steadier than the tubular ; 10 ohms is useful. Wireless firms sell many patterns at low prices.

Resistance Box : a good type is a plug box with brass blocks embedded in bakelite—they do not shift when a plug is removed.

Wire : for ordinary connections the most useful wire is D.C.C. copper, S.W.G. 20 or 22. For resistance, use Eureka or Constantan (manganin has to be imported), D.S.C., gauge from 18 to 36 or even 42 according to the resistance required.

Ammeters, Voltmeters : real switchboard instruments, first grade, from reliable commercial makers, are the most satisfactory ; 4 in., or better, 6 in. dial is desirable and a fine pointer ; also "educational finish" so that the "works" may be seen. A range of 0-10 amps. and 0-15 volts is useful if 12 or 14 volt supply is used on the bench ; if not, the instruments must be obtained to suit the voltage used. For class use it is convenient to have one 0-5 amps. for each pair of pupils, and one 0-1 and one in milliamps for every four ; voltmeters similarly. In the early stages it is wise to give boys separate instruments for finding voltage and amperage. The Universal Avometer and all-test instruments are valuable but do not withstand clumsy handling by juniors. Necessary accessories are : lamp-holders screwed on blocks of wood 3 in.  $\times$  3 in.  $\times$  1½ in., with bakelite terminals ; lamps—12 volt and 6 volt are useful ; rheostats to suit current and allow pupils to vary the voltage ; and a distributing board with switch and fuses.

Much use may be made of a lico switch, series socket, and tubular socket pieces : many valuable mountings for switches, reversing keys, rheostats, fuses, and the like can be made on electrician's blocks.

### *Demonstration Apparatus*

For apparatus of which only one or two are needed, the rule that it pays to buy good quality holds still more strongly. Thus cheap dip circles and stop watches are very unsatisfactory and soon get out of order even if they ever work properly in the first place. Requirements and preferences vary indefinitely, but



in general it may be said that the simple is to be preferred to the complicated, and the direct to the indirect. Accuracy, though desirable, is still a secondary consideration to comprehension; and where it is available, an instrument simple in principle, with few adjustments and easy to read, should be selected in preference to any other. In such cases, much use may be made of the school workshop at some saving of cost, though the product may lack some of the refinement and finish of the instrument maker.

All that can be attempted here is to give the young science master some idea of the various types available in order to help him in his choice of one of the more expensive instruments; much apparatus of this kind will be useful for advanced work with a sixth form. In general, however, he will find that it is often possible to devise an arrangement from ordinary laboratory stock which will not only work but give reasonably good results; such devices, being as a rule simple in principle, are often valuable for preliminary work. In many cases there are fairly satisfactory forms available at lower prices, and these may suffice for schools in which a high price would be prohibitive.

For Boyle's Law, the usual form consists of two glass tubes connected by pressure tubing and mounted on a stand; it is desirable to have a range of three atmospheres. If a graduated closed tube with tap is used, many gases (coal gas,  $\text{SO}_2$ , etc.) can be examined. A modification consists of two vertical capillaries connected by a horizontal loop of rubber tubing; pressure is applied to this by a metal plate and screw, thus greatly economising in mercury. In another form, but much more expensive, the air in a horizontal capillary is sealed by mercury, and pressure generated by a small hand pump and registered on a circular gauge. An arrangement based on the ordinary bicycle pump, described in the *School Science Review*,\* can be made easily in the school workshop.

Air pumps are expensive, but cheap ones are worse than useless and the "Tate" form should be avoided. The "Geryk" type, oil sealed and packed, is made in two forms for schools, portable, and rocker type. It gives an excellent vacuum, though it should not be used for showing water boiling under reduced pressure. A pressure gauge is a useful addition: the science master might consider an electrically operated pump and should do so in new laboratories.

\* *S.S.R.* Vol. V, No. 19, or *Science Masters Book I*, page 13.

A Fortin's barometer is necessary in most schools. If an Aneroid barometer is bought, the working parts should be clearly visible ; for the same reason a model water pump should be of glass.

For modern methods of cleaning mercury see G. Fowles' *Lecture Experiments in Chemistry*, 3rd Edition, 1947.

## HEAT

For the determination of coefficients of linear expansion many forms of apparatus are available. A simple form can be made, based on the upward expansion of a metal rod on which rests a pivoted lever ; more elaborate is a vertical tube which rests on a hinged horizontal lever reading on a vertical scale. A horizontal metal tube for steam turns a vertical pointer over a scale ; the use of a micrometer screw gauge naturally adds to the expense and the accuracy. A satisfactory form in which the expansion of a vertical metal tube is measured by a spherometer is not very expensive, but a substitute can easily be made in the workshop. Optical lever methods are becoming popular.

For the Mechanical Equivalent of Heat a useful type of apparatus for schools giving very good results is a simplification of Callendar's, in which a silk brake works on a horizontal brass calorimeter ; in a modification preferred by some, the rotor is a solid copper cylinder pierced with long holes. Searle's apparatus, consists of two concentric cones, the outer driven by a hand wheel or motor and the inner (containing water) prevented from rotating by weights over a pulley.

*Radiation Experiments.* Cheap thermopiles cannot be recommended. Nobili's are moderate in price. Moll's, made for school use, is very rapid in action and highly sensitive, but expensive. A low resistance, highly sensitive, galvanometer is required ; astatic type for bench work or d'Arsonval reflecting type for demonstration.

A useful source of radiation is a heating element to be obtained from electrical firms. Much use may be made of sensitive paper.

If Leslie's cube and a differential thermoscope are used, care should be taken to see that the dimensions correspond.

For showing the maximum density of water a silica flask may be used, or a coloured glass float in a cylinder. The usual form of apparatus has a thermometer and indicator tube fixed into a glass vessel containing one seventh of its volume of mercury ;

a useful size is made, suitable for the lantern. In addition to these, there will be required various forms of thermometer, hygrometer, and hypsometer; perhaps Clement and Désorme's apparatus, a fuel calorimeter (e.g., Darling's), and a Bunsen ice calorimeter.

### LIGHT

The modern tendency is to substitute for pin experiments, in the earlier stages, experiments with actual beams of light, and numerous forms of apparatus suitable for class use are now on the market. For these, darkening of the room is not necessary, though direct sunlight should be avoided.

Simple forms of spectrometer, costing less than £10, are of little value; a really satisfactory instrument, capable of accurate work, costs considerably more. Polarimeters in general are too expensive for school use, though one firm makes a school polarimeter at a reasonable price.

The tendency to-day is to dispense with the cumbrous optical bench; a cheap wooden form with sliders is often used; superior forms in metal or oak are available for lengths 1,  $1\frac{1}{2}$ , and 2 metres.

### SOUND

The horizontal sonometer is not suitable for demonstration work, even if the hanging weights are replaced by spring balances. A vertical form, to hang on a wall and used with either weights or spring balances is better. For a Kundt's tube, glass mounted on a wooden base,  $1\frac{1}{2}$  metres in length is desirable; if required for different gases, more must be paid for a form with brass taps and fittings. A demonstration organ pipe with glass front, to show nodes, is useful.

### MAGNETISM

The cheap forms of dip needle are useless; reasonably efficient forms were marketed in 1939 by one or two makers at about 30s. An accurate instrument, justifying the making of the various corrections, costs much more.

### ELECTRICITY

This branch of Science may well cost the science master as much as all the rest of his equipment put together. Before

embarking on such expense he must be unusually careful to ensure that the instruments he selects are of the range and sensitiveness required for the work he proposes to do.

Of the many forms of galvanometer only the barest indication can be given. Pointer instruments must have a vertical face and a long scale ; these, like reflecting galvanometers, are conveniently mounted permanently on the walls in suitable positions.

A simple lecture galvanometer with pointer moving over a wide horizontal scale is essential and not expensive. A sensitive moving-coil wall galvanometer with pointer costs more. Of reflecting instruments, the d'Arsonval and the Ayrton-Mather are fairly expensive, but to-day a combined mirror and pointer instrument is often favoured.

Ammeters and voltmeters should have their working parts visible ; moving-coil instruments are more costly than the gravity type. A demonstration instrument with 8 in. scale and transparent case and dial, and a daylight galvanometer with illuminated scale, are most useful.

For demonstrating induced and thermo-electric currents and similar phenomena, a useful device is to connect bench apparatus in series with a number of simple sensitive galvanometers. These are placed one on each bench and their indications can be observed by small groups of boys.

Resistance boxes are expensive if 0.1 per cent. accuracy is required. The usual form—brass blocks and plugs—should have glass sides.

An induction coil for instruction purposes may have the secondary winding sliding on runners : the price depends on the length of spark required. For school purposes a 25–30 mm. spark will be sufficient. Cheap coils should be avoided.

## CHEMISTRY

This will not require any large outlay on expensive apparatus ; most of what is required is readily put together from the component parts which form the usual stock of any laboratory. Much of the remainder is concerned with experiments on gases.

A voltameter for the decomposition of " water " varies in cost according to design and the amount of platinum ; the latter is expensive, but it is true economy to have substantial electrodes. Platinum loops sealed through glass should be avoided as they easily break off. A form for lantern use is made cheaply. A

combined apparatus for water and hydrochloric acid with platinum and carbon electrodes fitted with rubber corks can be obtained. An apparatus for the composition of sulphur dioxide and carbon dioxide by synthesis is desirable. A Bunsen's eudiometer—straight form—will be needed; the U-form costs more and should have an outlet (with or without tap) from the bottom of the open limb.

For gas analysis a Nitrometer (Lunge or Schiff), a Hempel gas burette, and absorption pipettes on stands may be obtained, also an explosion pipette.

A Victor Meyer tube and copper jacket for vapour density work costs very little; the small bottles are cheap. Apparatus for depression of freezing-point and for elevation of boiling-point is required. So expensive is the old form of boiling-point apparatus that the Landsberger form is generally used; a simplification of this can be obtained quite cheaply. Most teachers make up a satisfactory apparatus for the depression of the freezing-point out of test tubes.

Amongst other pieces of chemical demonstration apparatus may be mentioned an ozoniser, either a Siemens tube with tinfoil or a tube for use with dilute sulphuric acid.

Fowles' book on *Chemical Lecture Experiments* contains some useful arrangements, e.g., special apparatus for preparation of gases (p. 400); for the preparation of noxious gases on the lecture table (p. 138); and a practicable repetition of Lavoisier's calcination of mercury experiment (p. 66).

## BIOLOGY

A clinostat, to demonstrate the action of gravity, and an auxanometer, to record the rate of growth, can be bought, but with skill, ingenuity, and time, substitutes can be made at a small cost. Simple potometers set up by individual scholars can be supplemented by one of the larger and more accurate models for demonstration purposes, e.g., Ganong's Potometer. The same remarks apply to the Respirometer, Manometer for Root Pressure, Photosynthometer, and Osmometer.

One firm markets an auxanometer, the clock part of which is detachable and can be used as a clinostat. A simple auxanometer, to demonstrate growth, is easily fitted up (a light, counter-poised lever, giving a ratio 1-10).

For chick embryology an incubator is essential unless one can

procure eggs in various stages of incubation from a poultry farm. A simple, but efficient incubator can be made from a large biscuit tin partly filled with water in which is suspended a vessel to hold the eggs. The water can be kept at constant temperature by means of a simple thermostat.

A vivarium is easily made from a packing case, some glass and perforated zinc. It is much more difficult to make a watertight aquarium. If a large aquarium is desirable it is advisable to buy one. Petri dishes, glass jam-jars, rectangular glass troughs of all sizes, and earthenware pneumatic troughs are all useful.

Large bell-jars (height 10 in., diameter 12 in.), some with closed, some with open tops, are essential.

A small selection of stains and mountants should comprise : aniline chloride, borax carmine, eosin, Delafield's hæmatoxylin, picric acid, safranin, Canada balsam in xylol, oil of cloves, osmic acid, gum, chloral mountant (which makes permanent preparations without the necessity of dehydrating the specimen), and Sudan III.

A series of permanent microscopic preparations should include animal and plant histology, lower animals, and plants (useful when fresh material is not available and for test purposes), embryological preparations, and special animal and vegetable preparations for sixth-form work. These can be kept in cardboard boxes with cardboard trays or in a microscope slide cabinet. One mounted skeleton of each type studied is essential ; loose bones are also essential, but these can be prepared from the animals used for dissection (boil, clean, put in chloride of lime, clean again, wash thoroughly, dry).

Injected dissections are very expensive, and not essential, but undoubtedly can be of great use for advanced work. The amateur will find it exceedingly difficult to prepare such dissections in a permanent way and is advised to buy them if he needs them.

It is well that the biological laboratory should have its own apparatus and chemicals for the chemical work required in analysis of soils, animal and plant food materials, etc.

It should also have its own metre rules, thermometers, water bath, air oven, aspirator, balances (cheaper form of chemical balance in case), and weights.

Permanent diagrams of animals and plants are most useful as they save much of the teacher's leisure time. There is a wide

choice in the catalogues and many of the simpler ones can be made by the teacher on cardboard or cartridge paper. Small sheets of diagrams (which can be bought in packets) are also useful for large classes as they avoid eye-strain.

A biological laboratory requires large supplies of alcohol (under licence from Excise), formalin, chloroform, sand, bulb mixture, and shallow wood boxes for seedlings.

#### USEFUL ADDITIONAL FURNITURE AND EQUIPMENT

- (1) A pair of steps or sliding ladder.
- (2) A trolley with wheels (dumb waiter), preferably with its top of the same height as the demonstration bench.
- (3) Drying racks over sinks, made by boring a series of holes just under 2 in. diameter in a board, or by making a wooden grid with, say,  $1\frac{3}{4}$  in. interior mesh.
- (4) A small cupboard, with perforated base, over a radiator is useful for drying specific gravity bottles, etc., or for electrostatic material; also for germination experiments.
- (5) Stands fixed to the wall for special experiments.
- (6) Wide-necked glass bottles (e.g., commercial sweet jars) for pickled biological material; these must be air-tight or the alcohol evaporates; labelled boxes or tins for dry material which is to be stacked in cupboards.
- (7) Clocks. A most useful type is a 10-in. diameter clock, working on 50-cycle controlled frequency A.C. mains, with a large seconds hand in red. A bakelite finish is suggested for clocks to be used in chemistry laboratories.
- (8) Saucepans and enamelled mugs have been found cheap and effective as water baths.

#### *Sources of Apparatus*

Various articles can often be obtained cheaply from the actual manufacturers: the Post Office Directory—Trades Section—will supply addresses. This is more easily done if it is stated that the articles are required for teaching purposes, and they are ordered in standard quantities and of stock sizes. Thus, to take a few examples, rubber tubing can be obtained from Dunlop, spring balances from Salter, glass blocks and prisms from Chance or Parsons, lenses from spectacle-makers, electrical wire from wire makers (such as Lewcos), magnets from Darwin,

resistances from Zenith, ammeters and voltmeters from Crompton-Parkinson or Ferranti.

Considerable use may be made of the local ironmonger and of Woolworth's and Halford's stores. Much useful material, second-hand, may be obtained cheaply from marine stores, car-breaking firms, and dealers in electrical oddments.

Most well-known manufacturers of scientific instruments exhibit at conferences, such as those of the Science Masters' Association and the Incorporated Association of Assistant Masters. The following list includes firms exhibiting recently and advertising in the *School Science Review* :—

Baird and Tatlock, 14-17, St. Cross Street, Hatton Garden, E.C.1

W. and J. George and Becker, Ltd., 17/29 Hatton Wall, E.C.1.  
Cambridge Instrument Co., 13, Grosvenor Place, S.W.1.

G. Cussons, Ltd., The Technical Works, Manchester, 7.

A. Gallenkamp and Co., 17/29 Sun Street, Finsbury Square, E.C.2.

Griffin and Tatlock, Ltd., Kemble Street, Kingsway, W.C.2.

Philip Harris and Co., Ltd., Edmund Street, Birmingham.

Labgear, 16, Leys Road, Cambridge.

W. B. Nicholson, 166a, Bath Street, Glasgow, C.2.

W. G. Pye and Co., Granta Works, Newmarket Road, Cambridge.

Reynolds and Branson, Ltd., 12, Briggate, Leeds.

Townson and Mercer, 390, Sydenham Road, Croydon.

Standley, Belcher and Mason, Church Street, Birmingham, 3.

London Instrument Co., 51a, Bridge Street, Cambridge.

Brady and Martin, Northumberland Road, Newcastle-on-Tyne.

Dick, Son, and Lewis, Guildford Place, Taunton, Somerset.

Eureka Scientific Co., Ltd., Natal Road, Ilford, E.

Kernick and Son, Ltd., Moira Terrace, Cardiff.

In addition to these, many firms specialise in particular articles and materials. Amongst these may be mentioned the following :

#### FINE CHEMICALS

British Drug Houses, Ltd., Graham Street, City Road, N.1.

Harrington Bros., 4 and 7, Oliver's Yard, 53a, City Road, London, E.C.1. (Fine Crystals.)



Hopkin and Williams, Ltd., 16 and 17, St. Cross Street,  
Hatton Garden, E.C.1.

Johnson and Matthey and Co., 73/83, Hatton Garden, E.C.1.  
(Platinum.)

#### GASES

British Oxygen Company, Grosvenor House, Park Lane, W.  
and branches.

Carbon Dioxide Company, Distillery Lane, Hammersmith,  
W.6.

Imperial Chemical Industries, Millbank, S.W.1. (Small  
cylinders of chlorine.)

Boake, Roberts and Co., Carpenter's Road, Stratford, E.15.  
(Sulphur dioxide siphons.)

#### ALCOHOL

Methylating Company, 21, St. James's Square, London,  
S.W.1. (Industrial methylated spirit in 5 gall. drums—  
excise permit required.)

*Note.* See chapter 12, page 254. Much additional information  
on the supply of alcohol to schools is contained in the *School  
Science Review*, No. 41 (October 1929), p. 1; No. 44 (June 1930),  
p. 364; No. 45 (October 1930), p. 17.

#### FILTER PAPER

Evans Adlard and Co., Postlip Mills, Winchcombe, Cheltenham.  
("Postlip.")

H. Reeve Angel and Co., Ltd., 9 Bridewell Place, E.C.4.  
("Whatman.")

#### GLASS, PORCELAIN, ETC.

Chance Brothers, Ltd., Smethwick, Nr. Birmingham.

Thermal Syndicate, Ltd., Wallsend-on-Tyne. ("Vitreosil.")

Worcester Royal Porcelain Co., Ltd., 30 Curzon Street, W.1.  
("Sillax.")

#### RUBBER TUBING, ETC.

Dunlop Rubber Co., Ltd., St. James' House, St. James' Street,  
S.W.1.

## MICROSCOPES, ETC.

- Aldis Bros., Ltd., Hall Green, Birmingham, 28  
 C. Baker, 244, High Holborn, W.C.1.  
 R. and J. Beck, Ltd., 69, Mortimer Street, W.1.  
 Broadhurst, Clarkson and Co., 63, Farringdon Road, E.C.1.  
 Clarkson's, 338, High Holborn, W.C.1.  
 Cooke, Troughton, and Simms, Ltd., Kingsway North, York.  
 J. H. Dallmeyer, Ltd., Willesden, N.W.8.  
 G. B. Equipments, Ltd., Film House, Wardour Street, W.1.  
 E. Leitz and Co., 20, Mortimer Street, W.1.  
 Newton and Co., 72, Wigmore Street, W.1.  
 Ross, Ltd., Clapham Common, S.W.4.  
 J. H. Steward, Ltd., 406, Strand, W.C.2.  
 J. Swift and Son, 81, Tottenham Court Road, W.1.  
 Taylor, Taylor, and Hobson, Ltd., 150, Holborn, W.C.1.  
 W. Watson and Sons, 313, High Holborn, W.C.1.

## METEOROLOGICAL INSTRUMENTS

- C. F. Casella and Co., Ltd., Fitzroy Square, W.1.  
 James J. Hicks, 8, Hatton Garden, E.C.1.  
 Negretti and Zambra, 122, Regent Street, W.1.

## PUMPS

- W. Edwards and Co., Allendale Works, Southwell Road, S.E.5.  
 Pulsometer Engineering Co., Ltd., 39, Victoria Street, S.W.1.  
 (" Geryk " Pumps.)

## ENGINEERING MODELS

- Stuart Turner, Ltd., Henley-on-Thames, Oxon.

## ELECTRICAL MATERIAL

- Automatic Coil Winder and Electrical Equipment Co., Ltd.,  
 Douglas Street, S.W.8.  
 Baldwin Instruments Co., Ltd., Cumnor, Oxford.  
 A. C. Cossor, Ltd., Highbury, N.5.  
 Crompton Parkinson, Ltd., Chelmsford, Essex.  
 Elliott Bros., Ltd., Century Works, Lewisham, S.E.13.  
 Everett, Edgcumbe and Co., Ltd., Colindale Works, N.W.9.  
 Evershed and Vignoles, Ltd., Acton Lane Works, Chiswick, W.4.  
 Ferranti, Ltd., 36, Kingsway, W.C.2.  
 Foster Instrument Co., Ltd., Letchworth, Herts.

Gambrell, Bros., and Co., Ltd., 307, Merton Road, Southfields, S.W.18.

Mullard Wireless Service Co., Ltd., Century House, Shaftesbury Avenue, W.C.2.

Nalder Bros. and Thompson, Ltd., Dalston Lane Works, E.8.

Sifam Electrical Instrument Co., Ltd., Torquay, Devon.

H. Tinsley and Co., Ltd., Werndee Hall, South Norwood, S.E.25.

Weston Electrical Instrument Co., Ltd., Great Cambridge Road, Enfield.

Zenith Electric Co., Villiers Road, N.W.2.

#### MAGNETS

Darwin's, Ltd., 28, Victoria Street, S.W.1.

The Permanent Magnet Association, 301, Glossop Road, Sheffield, 10.

#### BIOLOGICAL MATERIAL

This is in a different category from that required for Chemistry or Physics, in that much of it must be obtained as required—specimens must be fresh or even living. Biology is, moreover, a comparative newcomer into the school curriculum, and the sources of supply are consequently not well known ; the following list has, therefore, been made fairly comprehensive.

C. Biddolph, Green Belt, London Road, Merstham, Surrey.—

Microscope slides and protozoa specimens.

Biological Station, Cork University, Lough Ine, Co. Cork, I.F.S.—

Marine, fresh water, and terrestrial plants and animals.

Biological Supply Company, Rhydyfelin, Aberystwith.—Fresh and preserved plant and animal material.

Mrs. M. W. Crack, Kirriemuir, Rowledge, near Farnham, Surrey.—Botanical and aquatic material.

L. Cura and Sons, Bath Court, Warner Street, Rosebery Avenue, E.C.1.—Aquarium and vivarium supplies.

M. W. H. Darlaston, Freer Road, Birchfields, Birmingham.—Microscopical preparations. Customers' own material mounted.

Flatters and Garnett, Ltd., 309, Oxford Road, Manchester, 13.

Microscopical preparations, lantern slides, biological apparatus and materials.

Freshwater Biological Laboratory, Wray Castle, Ambleside, Westmorland.—Fresh water specimens.

BIOLOGICAL MATERIAL—*contd.*

- T. Gerrard and Co., Ltd., 46/48, Pentonville Road, London, N.1.—Museum preparations, material for dissection, both living and preserved, biological apparatus.
- L. Haig, Beam Brook, Newdigate, Surrey.—Living material for aquaria.
- Marine Biological Association, Citadel Hill, Plymouth.—Marine specimens.
- J. E. Molloy, Dell Cottages, Cowley, Middlesex.—Frogs, skeletons, aquaria material.
- Miss M. R. Morley, Durnfords, Chiddingfold, Godalming, Surrey.—Botanical material.
- National Collection of Type Cultures, Lister Institute, Chelsea Bridge Road, S.W.1.—Fungi and bacteria.
- L. W. Newman, 42, Salisbury Road, Bexleyheath, Kent.—Breeder of British Lepidoptera.
- Port Erin Biological Station, Isle of Man.—Marine specimens.
- H. G. Rose, 9, Six Bells Lane, High Street, Sevenoaks, Kent.—Aquarium plants and sundries, living pupæ, etc.
- Standley, Belcher, and Mason, Ltd., Church Street, Birmingham, 3.—Cheap microscope slides, dissecting instruments.
- Surrey Trout Farm, Haslemere.—Crayfish, fish, frogs, fresh water mussels.
- J. R. Thomas, 7, Shakespeare Terrace, Lower Richmond Road, Richmond.—Amœbæ, rotifera, volvox, vorticellæ, etc.
- F. Ward, Taxidermist, Histon, Cambs.—Specimens mounted for school museums.
- Watkins and Doncaster, 36, Strand, W.C.2.—Collecting apparatus, store boxes, etc.
- Ted Williams, 4, Britannic Row, Ilfracombe, Devon.—Fresh dogfish.

## CHARTS

- Sidgwick and Jackson, Ltd., 44, Museum Street, W.C.1.
- University of London Press, Warwick Square, London, E.C.4.
- John Murray, 50, Albemarle Street, W.1.

*Home-Made Apparatus*

Every science master should possess and cultivate some ability in wood-work, metal-work, and glass-blowing, more especially

where no competent laboratory assistant is provided. He may also enlist the aid of the handicraft teacher, provided that he knows exactly what he wants. Be he never so skilful, however, he is likely to find that in this manner an undue proportion of his leisure hours will be consumed ; this is one more argument for a skilled laboratory assistant in all schools, not merely in the large or wealthy ones.

The science master will find the *Science Masters' Books* and *School Science Review* invaluable ; he may obtain useful ideas from the wireless and television papers, the *Model Engineer*, and the M.E. Handbooks, also the *Meccano Magazine*, and pick up hints at Science Masters' Association meetings and exhibitions by the Physical Society. The bibliography at the end of this book includes a number of standard works on laboratory technique.

#### APPARATUS AND THE LABORATORY WORKSHOP

It will be generally agreed that a small workshop should form an integral part of every science department. Such a workshop will in general be attached to the physics section, but in most cases will be called upon to be of service to other sections also. The first service of the workshop is to maintain the apparatus of the laboratories in a good state of repair.

Many science masters, especially those responsible for the teaching of physics, are at one time or another intrigued with the idea of making apparatus. This is probably due to a number of different reasons. The money available for the acquisition of new apparatus is often inadequate, and the making of simple apparatus, especially as no labour charges have to be met, enables the science master to do more with the money at his disposal. Time devoted to such work could often be more profitably spent, unless the apparatus so made is comparable in quality with the manufactured article.

Where, however, it is impossible to obtain apparatus of the design required from a manufacturer, then its construction in the laboratory is desirable. If the design is sufficiently successful it may be possible to arrange for it to be manufactured and marketed and thus to benefit other laboratories.

The remarks so far have referred to apparatus intended for the laboratory rather than for the lecture room. Apparatus for the latter can be of a more temporary nature and its construction can give much scope for individual ingenuity. It is here that the

workshop is essential as it is still important that the apparatus should be well made. Reasonable attention should also be given to the finish of each individual piece of apparatus.

## DESIGN OF APPARATUS

### (a) *Lecture Apparatus*

We have already pointed out that it is to lecture apparatus that the science master should devote his attention. There is plenty of scope for originality, and the designing and building of a piece of apparatus for this purpose is not unlike a small piece of research work. Only *one piece* of apparatus for a given purpose is required, and no particular care need be given to the quickest means of making.

### (b) *Laboratory Apparatus*

With apparatus for the laboratory, several identical pieces will be required, two at least and quite probably a dozen. The problem now becomes almost one of mass production. Every detail must be carefully thought out and costs must be considered. Probably several models will have to be made and tested. Jigs, templates, and perhaps tools, will have to be made or acquired; in fact, the methods of the manufacturer will have to be adopted. Indeed, many of the largest apparatus makers make in batches as small as half a dozen. It is clearly unreasonable for the science master to attempt the production of even the simplest apparatus in quantity unless he has special facilities and a flair for design and workshop organisation. Nothing is more deplorable than a wholesale collection of badly-made apparatus—no matter how simple—for the student to use.

## THE UNIVERSAL APPARATUS

There is at times something of a craze for the universal apparatus. Such collections of bits and pieces are alleged to be capable of being used for a large number of different experiments; such an idea gave birth to Meccano, but surely apparatus or parts of it used for a long period of weeks is hardly inspiring to those who use it. There is, however, much to be said for economy; and if by skilful design a piece of apparatus can be efficiently employed for more than one purpose by a simple addition or subtraction of several components that is all to the good.

## MATERIALS

This is an age of new materials, many of which may be employed with advantage in the construction of apparatus. One of the most useful is a high quality asbestos cement board commonly known as *Natural Grade, Sindanyo*. This material is an excellent substitute for both wood and metal. Where an insulating material is required there are many substitutes for ebonite to be had in the form of sheet, rod, and tube. These "bakelite" materials are not affected by sunlight as is ebonite, though they are somewhat more difficult to machine.

Where coloured insulating materials are needed erinoid (a casein product) is available in almost any colour. It is easy to work and takes a high polish, but should be used with caution, as it readily warps.

Non-inflammable celluloid (Rhodoid or Cellen) may be used as a substitute for glass. "Perspex" also is an excellent transparent material.

Science masters should make themselves acquainted with a number of proprietary materials which are now available as substitutes for wood and metal. Various synthetic "boards" are very useful in the laboratory, as are also some of the new plastics.

### *Extruded Brass, Aluminium, Duralumin*

A great deal of time can be saved in making apparatus if metal strips, bars, and rods of the correct size are available. It is then only necessary to cut off the required length and clean up to obtain a piece of material of the size and shape required.

Extruded metal in any of the above may readily be obtained as angles, tees, flat strips, bars, and rods, and a large variety of more complex sections—brass is most generally useful.

### *Buying Woods*

A correspondent sends the following advice on this subject :—

"In the matter of buying woods, advice should be obtained from the Timber Development Association, Ltd., 75, Cannon Street, London, E.C.4. This organisation would be able to advise where certain timbers can be obtained, and as to supplies of plywood on the market. Reference might also be made to one or more of the trade journals, and of these there is a very attractive

one now running called *Wood*, in the advertisement pages of which a number of reliable timber merchants have space.

"Plywood can be obtained from 3-ply to multi-ply of a large number of veneers. The 3-ply is to be had in varying thicknesses, but the most useful for making apparatus where panels are required to enclose some part, is about 3 mm. to 4 mm. thick. This thickness does not remain flat, but must be attached to a frame to keep it in position. The multi-ply, however, can be sawn into desired shapes and these will remain flat: 7- or 9-ply is usually adequate for making up apparatus.

"Birch plywood is probably the most useful and is generally the lowest priced hardwood board on the market, but it has very little decorative value. If plywood is required for some permanent piece of apparatus for which a good appearance is desirable, boards can be obtained with a very thin face veneer of one of the more decorative timbers, as, for instance, walnut or Honduras mahogany.

"Rare woods, e.g., ebony, are sold by the pound or by the inch cube, as in the case of first-class boxwood. Other hard woods are generally retailed by the superficial foot: soft woods by the foot run for framing or by the square foot for flooring or siding. Plywood is sold by the 100 superficial feet or by the bundle."

### *Miscellaneous*

#### FINANCE

Many teachers of Science do not seem to be unduly hampered either in their choice of apparatus or in the financial allowance for the purchase of apparatus. It is, however, desirable that more liberty should be given in many cases as to the choice of firms from which purchases may be made, and also that there should be less delay in the execution of orders which have to pass through official channels. It is suggested that a reasonable average expenditure on apparatus is 7s. 6d. per head per annum, with an extra allowance for sixth form work. This amount is, of course, for maintenance and not for the original stocking of a laboratory.

Each teacher should be granted an adequate allowance of petty cash, and receipts should not be expected by the authorities for sums under 1s. Some teachers are seriously hampered by red tape and pettifogging restrictions. To avoid these, some use breakage money for petty cash, or even pay out of their own pockets. In one case, experiments with ice have been given up



because of the time and trouble required to recover the money so spent.

If everything for the laboratory has to be bought through one firm—a common practice amongst local education authorities—secondhand apparatus is not available. This restriction must be condemned as inevitably promoting inefficiency. We understand also that the Stores Department system favoured by some local Education Authorities too often causes delays and is not efficient.

### BREAKAGES

Some schools make no charge for breakages, realising that boys have no choice but to perform the experiment and that it might be difficult to collect the fines when incurred; it is a useful reminder—as well as a help in stock-taking—to keep a breakage list posted up in the laboratory, to contain the name, article, date, *and cost*.

The majority of schools impose no fine in cases of accidental breakage, but for gross carelessness boys pay a small amount as a deterrent. Such fines are often on a definite scale, ranging from 1d. to 4d., 6d., or even 1s. in the case of a thermometer or burette. They are best collected on the spot, both for the greater effect when paid out of pocket-money, and also to save booking. Sometimes such fines are used for petty cash, or they may be deducted from the petty cash account at the end of term. In other cases, the fine is as much as half the cost of the article and a few schools are in a position to charge the full price. One school has an insurance system based on the previous term's breakages, the premium for which works out at 3d. a head per term on the average. This scheme is optional, but practically all boys use it.

### LABORATORY COATS

In a large number of schools no coats or aprons are worn—either on account of the cost or because their use is believed to make boys careless. Where such protection is worn in laboratories, it is generally optional, the advantages being pointed out; it is fairly general in sixth form work in Chemistry and Biology.

The usual form is a khaki drill overall. In some schools, particularly for Biology, white coats are preferred. White sleeves

are useful for dissections. Where coats are not worn, a light apron is advisable for occasional use, for staff as well as pupils.

### *Safety in Science Laboratories*

#### LABORATORY ACCIDENTS

The questions arising from laboratory accidents are treated in the chapter on First Aid in the Laboratory and, similarly, the legal position is dealt with elsewhere in this volume.

Additional suggestions are to be found in the pamphlet, "Safeguards in the Laboratory," compiled by the Science Masters' Association and the Association of Women Science Teachers. This pamphlet, price 7d. post free, is obtainable from the Librarian of the Science Masters' Association.

Chapter XII of this book deals with the legal liability of teachers for accidents. Still further reference may be made to two articles in the *School Science Review*, "The Law and the Laboratory," by a barrister-at-law (Vol. X, No. 40, p. 302) and "First Aid in the Laboratory," by A. G. Huggett (Vol. XI, No. 41, p. 17).

#### PRECAUTIONS

(1) The following articles should be kept in each main laboratory in an easily accessible place and where they can be checked at least once a term :—

- (a) A woollen rug or blanket to extinguish clothing which has caught fire.
- (b) At least one bucket of sand.
- (c) A chemical fire extinguisher.
- (d) A first-aid outfit, the S.M.A. pamphlet and warning card. All science teachers must be familiar with the contents of the outfit and pamphlet and be able to use the materials provided.
- (e) A sheet of Triplex or similar glass to act as a screen during experiments involving explosion.
- (f) A sheet of asbestos for placing on a bench during experiments with inflammable materials.

(2) The doors of a laboratory should not be locked when pupils are inside, but they must be locked when the laboratory is unoccupied.

(3) No pupil should enter a laboratory or other science room except under the direct supervision or instructions of the science teachers responsible, or of the headmaster or headmistress.

(4) Reasonable precautions should be taken to ensure that :—

- (a) Stock bottles of concentrated acids, alkalis, and inflammable liquids are kept in a preparation or store room which is inaccessible to pupils.
- (b) All substances which are scheduled poisons are kept in a locked cupboard, the key of which is in charge of the teacher.

### EXPLOSIONS

Opinions differ as to the experiments which are actually dangerous and it can be assumed that very few materials are dangerous in the hands of skilful and careful experimenters. All teachers, however, should assure themselves that they are taking adequate precautions when making experiments with hydrogen, and that their pupils understand the danger of lighting a jet of hydrogen without first testing a sample of the gas collected in a test-tube.

Adequate precautions should also be taken with experiments involving coal-gas, sodium, red or yellow phosphorus, concentrated acids, ether, carbon bisulphide, ammonium nitrate, chlorates, and in the grinding or heating of explosive substances.

For the benefit of less experienced teachers it may be useful to state that accidents have been known to occur in the following cases :—

- (1) Explosive mixtures of hydrogen and air have been formed
  - (a) when sodium wrapped in iron gauze has been placed in water ;
  - (b) when an “ empty ” sodium bottle with the stopper in was left in a sink for washing up ;
  - (c) during the synthesis of water from hydrogen and copper oxide ;
  - (d) when naked flames were allowed near a hydrogen generator, even when the latter was on the far side of a double bench ;
  - (e) through incomplete displacement of air from a Kipp’s apparatus.
- (2) Explosive mixtures of solids have been given for analysis,

e.g., aluminium powder and red lead, magnesium powder and potassium dichromate.

(3) Chemicals have been returned by pupils to the wrong bottle, e.g., potassium chlorate to the potassium nitrate bottle. (Pupils should be forbidden ever to return chemicals to bottles.)

(4) Potassium chlorate has been known to explode when it was heated with manganese dioxide. The latter may have contained coal dust as an adulterant or even, in one case, 10 per cent. of antimony sulphide. It is wise, therefore, to make a preliminary trial with a small quantity of the manganese dioxide which is to be used.

(5) Phosphorus when heated in chlorine to form phosphorus trichloride has blown up unaccountably.

(6) The action of water on sodium peroxide has proved explosive owing to the impurity of the peroxide.

(7) Potassium metal extracted by the old method may be violently explosive.

(8) The action of concentrated sulphuric acid on potassium permanganate may be explosive.

(9) It was made illegal by an Order in Council (after a serious explosion in a senior school) to mix potassium chlorate with either phosphorus or sulphur; the making of gunpowder even in small quantities has been deprecated by the Home Office. Board of Education Administrative Memorandum No. 167 is also relevant.\*

(10) The use of grease on the tap of an oxygen cylinder has caused an explosion.

## FIRES

Phosphorus residues and pieces of unquenched charcoal left in wooden rubbish containers have led to fires; it is therefore general practice to use metal receptacles.

## ACIDS AND ALKALIS

The store of concentrated acids and alkalis should not be accessible to pupils and the bottles should be on or near floor level.

Concentrated acids in use should be kept at bench level and the bottles should stand on a plate or shallow dish.

A winchester of concentrated acid should never be carried by the neck alone.

\* See Appendix IV, p. 273.

Concentrated nitric acid on the skin should be washed off at once with water.

Care should be taken when filling pipettes with sodium hydroxide or similar solutions.

Many solutions, e.g., copper sulphate, are seriously corrosive to clothes and books.

### CUTS

Pupils should be instructed in the handling of glass apparatus, the rounding off of glass edges, and, in particular, in the correct method of inserting glass tubing into a bored cork.

### POISONS

All substances scheduled as poisons, i.e., those for which a signature in a poison register is required unless sold for professional purposes, on *bona fide* signed orders, to qualified persons and authorities, should be kept in a locked cupboard or store.

Substances likely to be found in schools include :—

Antimonial and arsenical compounds.

Barium salts, except sulphate.

Dinitro-cresols, naphthols, and phenols.

Hydrocyanic acid and cyanides.

Lead compounds.

Mercuric salts.

Nitrophenols.

Sulphonal.

Many other substances are poisons but not "scheduled poisons" and care should be taken with 0.88 ammonia solution, chloroform, all concentrated acids and alkalis, ether, and nitro-benzene.

### LABORATORY RULES

The use of printed rules may be regarded as unnecessary in schools where the discipline is good and the classes not too large, but for their own protection teachers are well advised to post up in their laboratories some such list of rules as those published by the Science Masters' Association. Alternatively, the list of rules may be printed and a copy stuck in each science note-book. The rules made should be few and directed to ensuring freedom from accidents and to the smooth running of the laboratory.

The following are suggested as a basis :—

(1) Pupils are not allowed in the laboratory unless a master or mistress is present.

(2) Laboratory materials are not to be taken out of the laboratory.

(3) Solids are not to be put into the sinks.

(4) Chemicals should not be tasted and should be smelled with care.

(5) Small quantities only of chemicals should be used unless instructions to the contrary are given.

(6) Breakages and accidents must be reported immediately to the master or mistress in charge.

(7) After use, apparatus must be cleaned and replaced, and the bench left clean.

(8) Water and gas should not be wasted and should be turned off before leaving the laboratory.

#### LABORATORY ASSISTANTS

There is an urgent need in over 80 per cent. of secondary schools for adequate laboratory assistance : in less than 20 per cent. of schools can such assistance be considered as satisfactory. In over 40 per cent. there is no assistance of any kind whatever ; and 73 per cent. of schools with less than 250 pupils have no laboratory assistant. Many authorities, too, compel the assistants to leave at ages varying from 18 to 21 unless they become " technicians."

The situation is deplorable, and at the present time there is no matter more relevant to the improvement of science teaching than the provision of proper laboratory assistance. It is unfortunate that many authorities appear unable to appreciate that a little further expenditure would produce a much greater improvement in efficiency.

Existing assistants seem to fall naturally into two groups :—

(a) The skilled laboratory steward. As a rule such a man is only to be found in schools above 500 in number. The Committee feels that every school teaching a reasonable amount of Science should have at least one assistant of this category.

(b) The unskilled boy, capable of tidying up, etc. This is considered by many to be a blind alley occupation, though it need not be so. The employment in the school of a boy who is in need of financial assistance to continue his studies usually proves unsatisfactory.

At present there are no standardised qualifications which a laboratory assistant may be expected to possess, though the Institute of Physics and the Institute of Bacteriological and Pathological Assistants issue diplomas for work in their particular subjects.

The Science Masters' Association have prepared a comprehensive scheme whereby a boy may start in a school laboratory at or about 16, *under the supervision of a senior steward* (together with the science master) and will receive an adequate training according to a syllabus of work drawn up. When he has gone through the course of work (initiated by a holiday course of two weeks), the assistant will be examined in his own laboratory by a panel of examiners appointed by the Science Masters' Association. If the assistant gains a certificate of proficiency his wages are automatically increased according to a fixed scale. Such a scheme—here outlined but briefly—would seem to be deserving of every support as soon as it can be brought into operation.

More recently an Association of Laboratory Stewards has been formed, and no doubt among their first tasks will be the laying down of suitable standards of qualification for skilled assistants and the initiation of suitable training courses.

Where a laboratory steward exists, his duties should be clearly defined and distinct from those of the school caretaker or the school porter. Thus the caretaker would clean all floors, windows, etc., while the laboratory steward would attend to benches and apparatus.

Adequate free periods should be allowed to all science masters in order to cope with the additional work involved in running a laboratory. Six free periods in a 36-period week is considered to be a reasonable allowance, with additions for masters or mistresses in charge of departments.

## CHAPTER V

### METHODS OF SCIENCE TEACHING

Many different methods are available to the teacher of Science. Which of these he will adopt in any particular case will depend on many factors : his aims, his interests, his training, the intelligence or enthusiasm of his pupils, the resources of his laboratory, and his power of arousing the co-operative interest of his class. Any account of teaching methods is bound to meet with both approval and disapproval in fair amount, but it is with a view to helping young teachers and also those older ones who are prepared to consider suggestions of methods different from those to which they are accustomed, that the present chapter has been compiled.

Whatever views the teacher of science may have concerning the aims and methods of Science in general, he should eventually use those methods which experience convinces him are best suited to his own personal interests and abilities. Methods which one teacher employs with success may in the case of another prove hopelessly impracticable ; especially is this true of those teachers possessed of only weak disciplinary powers.

Successful and experienced teachers of Science agree, however, on a few fundamental principles of method. They all believe that practical work and first-hand experience of things are essential, that their pupils must be encouraged to express their ideas in clear and accurate language, that strenuous work is desirable. But they deal with their subject in so many different ways that it is difficult to describe methods of procedure which they would all adopt or which they would all consider the best. In consequence, all that can be attempted in the present chapter is to describe briefly different ways of teaching and of organising syllabuses, and to give advice which many good judges consider sound.

In most schools Science is taught by a combination of classroom and laboratory methods. The more theoretical parts of the subject are dealt with by lecturing, discussion, and oral and



written questioning familiar in other subjects. Where possible, the teacher's descriptions are amplified and enlivened by demonstration experiments, and where suitable the problems involved are investigated practically in the laboratory by the pupils themselves. Here they endeavour, besides trying to gather information for themselves, to verify some of the propositions they have learned, to acquire skill in simple manipulative processes and to familiarise themselves with the properties of materials and of apparatus.

Many reformers have suggested that methods of this kind, which treat the class as a unit, should be modified or abandoned. They urge that more attention should be paid to the varying needs and capacities of individuals, and to the desirability of throwing them more on to their own resources. Three of the proposals made deserve examination.

### THE PROJECT-METHOD

The essence of the project is the carrying out of a useful task by a group working co-operatively—the activity, the utility, and the co-operation are all stressed. For instance, either the whole class or a group of pupils may be set to equip a school meteorological station, or to build an astronomical observatory, or to run a school garden or farm, or to arrange the school stage, or to instal a small telephone system.

In order to carry such tasks to a successful conclusion, the pupils themselves would have to learn a good deal of science ; they would see how theoretical knowledge is needed for practical tasks ; they would familiarise themselves with materials.

When the job is completed, arrangements must be made to pool and to share the new knowledge—the teacher must see to it that the pupils learn from each other. This can be done by exhibitions, by lectures or demonstrations given by pupils, and by ordinary lessons.

Projects play an important role in the educational systems of Scandinavia and of the United States. At one time the "project" was the only method of science teaching admitted in the U.S.S.R. where, however, it was abandoned in 1931 in favour of "polytechnisation." The reason for that reversal of policy was that when the pupils arrived at the university or technical high school they were insufficiently equipped theoretically to follow the courses offered. "It gave the children a superficial knowledge

of a great many things, but no proper groundwork of the foundation of education." These defects may have been due to the inexperience and lack of training of the teachers. The method certainly works best where classes are small, where there is an ample supply of material and of apparatus, and where adequate time is available.

### GROUP METHODS

In these the class is divided up into small groups of four or five children and to each of these groups a specific task is allotted (e.g., to make a model steam engine or to determine the specific gravity of a number of liquids). A group leader is appointed whose job it is to see that the task is successfully completed, that all share in the work, and that each member of his group keeps in touch with all that is being done.

Obviously, few teachers would wish to employ *only* such a method. Yet all those who have observed such groups at work are convinced of its value and think that occasional use of this method is useful and worth while.

### THE DALTON PLAN

It is possible, with special care and preparation, to teach as many as seven or eight individuals at once, allowing each to work at his own pace, and allowing them to study different topics or subjects. The pupils waste no time listening to familiar explanations or to descriptions of things they know ; each pupil proceeds at the pace best suited to his capacity ; there is less chance of weaklings being allowed to skip over difficulties ; the course can be suited to each individual's tastes and interests. Evidently such a method can be used in the sixth form, if it contains only a few pupils. Certainly, there is little excuse for a teacher who consistently applies a class method when he could use an individual one.

Since excellent books are available in which this method is fully explained, it is unnecessary here to attempt detailed description. A programme is carefully planned and worked out in consultation with the pupil. The assignment may be given in broad outline for a term's work, and in detail for a month ahead. Thus each pupil will know what he will be expected to accomplish by the end of the month, what books or what parts of books he will be expected to read and study, and what exercises and

experiments he should do. He is then left to proceed as he will, although he may consult the teacher whenever he wishes and may attend specially arranged classes.

This system requires highly skilled teachers, and sets a great strain on them. Probably most schools are insufficiently staffed to make much use of it. Nevertheless, it could sometimes be used to great advantage with the upper forms and might occasionally be useful even earlier.

#### CLASS DISCIPLINE

If freer methods are to be used successfully, exceptionally skilful teachers are necessary. Furthermore, the standard of discipline in the school must be very high. This does not, of course, imply that the school must be one in which rigorous order is insisted upon. For order and discipline are not synonymous terms.

No one can teach well unless the discipline in his classes is good and teachers are, probably rightly, judged largely in the light of their disciplinary power. Yet it must be stressed that the orderly behaviour of a class is only an index, and occasionally an entirely fallacious one, of discipline. Some teachers obtain quiet, passive, and silent behaviour—the discipline may or may not be good. If the pupils work hard and learn happily, if interests are aroused which are continued in after life, then the discipline is good. If not, the contrary is true.

Science teachers vary widely in the standard of behaviour on which they insist. Many dislike a class being too quiet. They prefer the pupils to be lively, to ask and answer questions readily, to contribute to the discussion and generally to take an active part in the lesson. A casual and superficial observer looking into their rooms might even think the class rather disorderly.

Those who have little experience of teaching usually have some disciplinary difficulties, tending to be too strict or, more commonly, too lenient. This is to be expected and should cause no undue worry; experience will correct the defects. At the same time the young teacher must bear in mind that his headmaster is frequently not a science master and may not always appreciate to the full the special difficulties of discipline in a laboratory as compared with that in a classroom.

#### ORGANISATION OF SYLLABUSES AND COURSES

The content of the science courses for the four to eight years which pupils spend at a secondary school is often decided mainly

by the syllabus of the examination taken at the end of the course. The syllabus is influenced also by the interests and capacities of the teachers and the aptitudes and demands of the pupils. The continuous influence of the examination is in many ways unfortunate since schools cannot fit their courses to local conditions as closely as is educationally desirable. It would be well if more schools could avail themselves of the possibility of using their own special School Certificate syllabuses.

Though most teachers consider it advisable to keep fairly closely to material listed in examination syllabuses, at least during the last two or three years of the School Certificate course, it is quite unnecessary to keep within these bounds the whole time. For instance, even if only Physics and Chemistry are offered in the School Certificate, it is still possible to teach General Science (including Biology) during the first two or three years.

Whatever method of syllabus arrangement is adopted, certain general considerations apply.

The course as a whole must follow a definite, clear, and orderly plan. In arranging each part, account must be taken not only of what has gone before, but also of what is to come. Points of special difficulty must be prepared for and difficulties separated, so that the pupils, as far as possible, are called upon to face only one difficulty at a time. The plan should be clear and simple enough for the pupil to understand it and to take an intelligent interest in his own progress. He should not be expected to go on in blind faith, but should be able to see what his work is leading to.

The course of the work should be divided into clearly marked sections, of which each should be completed in a reasonable time. So far as possible the work of each year and the work of each term should be complete, while leading on naturally to the work of the next year or term. Each term's work should be divided into groups of lessons of which each group covers the development of a single topic. Such a "method unit" rather than a single lesson should be the unit of instruction, that is, lessons should not be planned in isolation, but the method unit should be thought of as a whole.

Method-units dealing with different parts of science necessarily differ in character. Speaking generally, however, a method unit shows the following four stages :—

The introduction, or preparation, the purpose of which is to give the pupils a clear idea of the problem to be solved, and

to make them interested in solving it. Here the teacher will probably indicate the phenomena to be investigated or bring out the necessity for a piece of apparatus which is to be used.

In the second stage, that of presentation, the class investigate the problem practically and the teacher gives his demonstrations or explanations.

Then follows formulation, in which the results of the investigation are reviewed, reduced to definite form, clearly stated and learnt.

The purpose of the final stage, that of application or review, is to give mastery over what has been learnt by giving examples and by requiring the pupils to apply their knowledge to fresh but similar (though perhaps more complex) problems.

It will be noticed that the scheme described above often takes the form of analysis followed by synthesis. For instance, in dealing with anything that involves complicated description, it will usually be best to give a general idea of the matter as a whole, avoiding details, then to consider the details in order, and finally to reconsider the whole matter with the details. The same procedure can generally be followed in dealing with a question of theory. In other words, the pupil should have in his mind an outline into which the details, as they are reached, take their proper place. He will thus know whither the argument is carrying him. A synthetic method not preceded by analysis often leaves him in the dark and confuses him.

Certain maxims of teaching method have been formulated and deserve consideration. They embody traditional lore and summarise a vast amount of experience. "From the known to the unknown" reminds us that it is necessary not only to link each lesson to what has come before, but also that it is well to make full use of the pupils' out-of-school observations, knowledge, and interests. "From the particular to the general" stresses the importance of inductive teaching. It is usually best in science teaching to start from particular cases and to formulate the rule or conclusion from them. "From the simple to the complex" is to be interpreted as meaning from the psychologically simple (i.e., from the concrete and familiar) to the psychologically complex (i.e., the abstract and unfamiliar). This maxim may be amplified by others—"from the empirical to the rational," "from the concrete to the abstract and back again to the concrete."

## METHODS OF ARRANGING SYLLABUSES

Some methods of arranging syllabuses are set out below. It will be obvious that no teacher will employ one method to the exclusion of others—they are separated here only for convenience.

*Logical Arrangement*

Euclid's *Elements* is an excellent example of a course of study arranged logically. Euclid begins by postulating a few axioms. These can be "verified" by crude observation and appear quite obvious. From these axioms a whole body of knowledge is derived by processes which (apparently) entail nothing beyond the common sense laws of deductive logic.

It is possible to write scientific treatises, or even text-books for schools, on this model. That is, one may attempt first to give definitions of the terms used (e.g., temperature, specific heat), and to establish general propositions (e.g. the laws of thermodynamics), making the latter appear as obvious as possible. From these as many consequences as possible may be deduced. Such attempts have varying degrees of success; naturally, the more quantitative and mathematical the subject the easier does the task of the writer become. It is very probable that this factor has been responsible for making school science more quantitative and mathematical than it would otherwise have been.

It is not by any means certain that the features which are characteristic of Natural Science can be well shown in treatises written on this model. Faraday's *Experimental Researches* provide a model that deserves at least as much consideration as Newton's *Principia*, especially when work in schools is being considered. In particular, it is difficult to exhibit the scientist's urge to discovery when a finished body of work is being described; or to exhibit an inductive method of approach in a treatise arranged deductively, or to stress empiricism in a rational development. In other words, the empirical and experimental elements in scientific thought make it difficult to write good deductive treatises. Modern research has shown that even Euclid's demonstrations contain unproved premises.

In practice the purely logical model has been abandoned by most teachers, and even in mathematics the Euclidian sequence and method is now but seldom followed. Nevertheless, text-books still retain remains of the courses current forty years ago, when many school-books were little more than abridged versions

of university treatises, with all the difficult parts left out. Since text-books exercise a powerful influence on syllabus organisation this may prevent teachers from adopting schemes more in touch with modern conditions.

### *Historical Methods*

The aim here is not so much to show the logical organisation of Science as to exhibit it as a method of solving problems which have changed and evolved for many centuries. Furthermore, historical methods can easily be used in such a way that the learners never attach undue weight to particular formulations or to particular theories. A beginner who has seen how the beliefs of scientists have changed during the centuries, and has observed how one theory displaces another when the latter fails to fit the facts, is less likely to believe that the latest theory is the absolute truth. Such a person is already half way to a proper appreciation of the difference between fact and hypothesis.

So far the historical method of development has been little used in school courses or in elementary text-books. There are several ways of using historical methods.

*Anecdotal.* This is the most common use of historical material. Into a course, arranged say, logically, amusing details of the lives of the scientists or interesting stories of scientific discovery are introduced. This has considerable value : it may whet the appetite of the learner, may make him aware of the fact that scientific progress results only from the work of individuals and may make him reflect on the qualities that make for success in Science.

*Biographical.* Some teachers, who have been fascinated by the personalities and achievements of great men and who believe strongly in the force of personal example, have suggested that it might be possible to build up a satisfactory syllabus in Science by studying the life and work of the pioneers. For instance, one might select Copernicus, Galileo, Gilbert, Harvey, Boyle, Newton, Black, Priestley, Lavoisier, Davy, Faraday, Pasteur, and Lister. and develop one's course around the story of their achievements.

Presented dramatically, such material appeals to many boys and may be especially useful with sixth formers who are specialising in literary subjects. Every teacher will endeavour to bring such material into his lessons incidentally.

*Methodological.* The best-known example of a treatise written

on the history of scientific methods is Ernst Mach's *Science of Mechanics*. For the teacher, books of this kind have the highest value and interest, but considerable knowledge and critical powers are required properly to appreciate and to understand them.

*Evolutionary.* As the name implies, courses in some parts of Science can be arranged to show how these parts have developed. Such a method stresses chronological order. It shows how each theory fitted the state of knowledge at the time it was developed, and how the theory was abandoned when fresh ideas came to light. The educational value of the method is great, for it often reveals how stubbornness and inability to put the actual results of experiment before theory have so often retarded progress; it helps to remove the attitude of mind of regarding former theories as completely wrong and the present ones as necessarily entirely correct. Unfortunately, it is difficult to apply the method widely--such subjects as combustion and the theory of solutions, however, are often taught in this way.

*Social.* A course in Science can be arranged to show that Science is a social venture, the result of which is the transformation of society; that scientists are engaged in tackling problems of immediate importance and interest to every individual; that new knowledge gives us new powers which, rightly used, would better man's lot.

Professor Hogben's books, *Mathematics for the Million* and *Science for the Citizen* are well-known examples. School courses may, in time, be affected profoundly by these newer ideals, but so far the effect has not been great. Children seem somewhat less responsive and interested than adults in this way of handling Science.

### *Concentric Methods*

Here the work done during each succeeding year covers the whole of the course in growing detail; the syllabuses given in the Science Masters' Association Interim Report on "The Teaching of General Science" are an example. A concentric scheme can be combined with any other of the methods mentioned. The chief advantages of concentric arrangements are that they facilitate revision and that it is easier to grade the work to the growing powers of the pupils. If, for instance, the whole of the School Certificate work on Heat and Light is done during the first two years and the work on Electricity and Magnetism during the two years following, difficult work and calculations on



Heat will be done during the second year and easy work in Magnetism and Electricity will be done during the third and fourth years. These difficulties are avoided by a concentric arrangement of the syllabus.

### *The Topic Method*

This method of arrangement has long been favoured by many who advocate general science courses in the elementary stages. For instance, it is recommended in the Ministry of Education pamphlet on "Science in Senior Schools" and in a similar pamphlet issued by the L.C.C. Education Department. Here the teacher suggests to the class topics of general interest which are then studied scientifically. "The Camera and the Cinema Projector," "The Gramophone," "Heat Engines," "Fuels," "Chalk," "Food-Plants," "Disease," are examples of such topics.

The chief advantage of this method is that the pupils easily understand the point of the lessons and immediately appreciate the utility of what is being taught. Furthermore, the principles of Science are met with in concrete situations; they are thus learned in a more usable manner. The chief disadvantage of the method is that it does not easily lend itself to the building up of a coherent scheme. There is, however, no doubt that "topics" are a very useful teaching device, especially during the first one or two years of the course when the importance of establishing logical connections is less than later on.

### *The Unit Plan*

This is a more mature and organised development of the topic mode of arrangement. It has the great advantage that the units can easily be combined with project activities. Examples of "units" are :—

- How does man provide his food supply ?
- How does man construct his buildings ?
- How does man protect himself from infectious diseases ?
- How are electric currents obtained and used ?
- How does man use energy for communication ?

Every unit of this kind is, of course, much too broad and inclusive. Class discussion, however, leads to an analysis of the unit and a breaking down into a number of related topics. Thus

the unit "How does man obtain and control the energy of fuels?" might break up into :—

- (1) What happens when materials burn ?
- (2) How are our important fuels obtained ?
- (3) How is the heat produced by the fire regulated ?
- (4) How can we conserve our fuel supply ?
- (5) How are destructive fires controlled ?

Each of these sub-units is then studied in detail. It is clear that this mode of arrangement combines many important advantages. It is likely to be adopted increasingly, especially in lower forms.

### *The Heuristic Method*

The heuristic method was suggested and used by Professor Armstrong largely as a reaction against the didactic methods used in teaching Science. The basic idea of the method is that the student should from his own observations and experiments discover everything he learns about Science. Instead of imparting facts, the teacher guides the student to discover them for himself and by this means trains him in scientific method.

Teachers find that the use of the heuristic method alone gives very slow progress. It is extremely difficult also to carry on the method consistently without making much of the so-called discovery very like make-believe. The idea behind the method, that the pupil should, wherever possible, be helped to make observations and discoveries for himself is, however, widely used by science teachers. (See pp. 8 and 143.)

### *The Co-ordination of Theoretical and Practical Work*

In organising a syllabus the teacher of Science is confronted with the problem of the correct relation between the theoretical work of his pupils and their work in the laboratory. There can be little doubt that ideally the two should be very closely related. A serious difficulty is, however, that such an arrangement makes little allowance for different pupils working at very different speeds. Complete connection is often difficult ; in Chemistry, for example, the practical work on volumetric analysis will take far longer than the appropriate theory, but adjustments are usually comparatively easy to make. Courses of practical work

quite divorced from theoretical work, as were some old-fashioned courses in Qualitative Analysis, are of little value.

In some schools the practical work of pupils taking advanced courses has sometimes to be arranged separately from their theoretical work, though careful thought will often show how to defer practical work on a particular subject until the appropriate theory is being done.

*The Relation of Syllabus Arrangement to the Psychological Development of the Pupil*

There is one other principle of syllabus arrangement which should be considered. The normal interests of children and adolescents pass through a series of stages. Whitehead speaks of romance, precision, and generalisation ; Nunn of wonder, utility, and logic. Interest in any topic usually starts in wonder. Later a pupil may ask about the utility of the new thing and desire precise information. Later still comes the stage at which a student tries to relate the new knowledge to the old, when he wishes to see the general through the particular, and attempts some sort of logical or philosophical unification. These different interests are not equally strong in all individuals at the same age, nor in the same individual at different ages. The logical or philosophical stage appeals mainly to intelligent adults, and then only in certain fields where they possess special knowledge. To arouse the interest of children it is best to appeal to their sentiment of wonder, to their collecting instinct, to their desire to do useful things rather than to rely on the adult appeal of pure logic—or even to the need of passing examinations.

A syllabus of work should evidently be constructed in the light of these considerations. Room should be made at the beginning for work which allows children to see wonderful and exciting things and which appeals to their feeling that Science is a romantic and adventurous pursuit.

Thus courses in practical measurements involving exact and precise work are out of place in the early stages—they too often act as a deterrent against future scientific enthusiasm. Later the pupils will make their knowledge more precise, and their growing social awareness together with their vocational interests will drive them to study things useful to themselves and to the community. This is the stage when “units” of the kind already mentioned might play an important role in harnessing the adolescent’s

enthusiasm and in preparing the way for the building up of interests which have permanent value.

#### CORRELATION BETWEEN THE TEACHING OF SCIENCE AND THAT OF OTHER SUBJECTS

Experience shows that a pupil's interest is aroused when the teacher of one subject utilises the knowledge which the pupil has associated with the work of another teacher. Such correlation tends to break down a prevalent habit of mind which assumes the storage of knowledge in separate compartments.

Only general suggestions can be offered for such correlation, which implies conscious co-operation between the teachers of various subjects.

*Science and Literature.* There are excellent works in Biography and Natural History and on discoveries and inventions. These can be recommended for class and home reading as literature.

*Science and History.* The life of a nation is greatly influenced by the application of scientific discovery to national trade, industry, diet, and standards of living, and by the impact of current scientific thought on the general ideals of the age.

*Science and Modern Languages.* Elementary books used in foreign countries for science teaching might occasionally be read. More advanced foreign text-books on special subjects should be placed in the school library.

*Science and Classics.* The nomenclature of Science is mainly classical and the recognised system of naming species is based on words-derived from Latin and Greek. Latin was the international language of mediæval Europe. Passages from Newton's *Principia* may be quoted ; they will strike a note of novelty in most classes on mechanics.

*Science and Mathematics.* Many problems of proportion, inverse ratio, equations, and graphs are constantly in use in science courses.

The early introduction of the trigonometrical ratios is a great help in the science course and their use in mechanics, magnetism, and light gives reality to their meaning.

A complete list of the parts of more advanced mathematics required for the advanced courses in Physics and Chemistry can be supplied to the Mathematics teachers. The time at which they are taught can frequently be made to suit both Science and

Mathematics. The requirements in the calculus, for example, are surprisingly small.

We feel that the teaching of Mensuration, whether treated experimentally or not, should definitely be a part of the Mathematics course, and that it should not be a specific charge upon the Science syllabus.

It is doubtful if the early teaching of contracted methods in Arithmetic, and of logarithms, is of advantage to the pupils in either course; but the meaning of significant figures and the intelligent use of approximations is most important to both courses and in everyday life.

We would also stress the need for greater accuracy in geometrical drawing.

*Science and Applied Mathematics.* In some schools Mechanics is treated as part of the science course and the treatment is experimental. Junior classes do experiments with levers and spring-balances and weights slung over pulleys to establish the principles of statics.

Fletcher's trolley, Atwood's machine, and Hick's Ballistic Balance serve to illustrate the Laws of Motion; experiments with the simple pendulum, with loaded rods, and a heavy wheel furnish data for the study of circular motion, moments of inertia, and moment of momentum.

Where laboratories are equipped with full-scale workshop machines, these yield results from which the variation of physical quantities can be studied. Even where laboratories are not so equipped, apparatus for the study of Mechanics and Applied Mathematics can be purchased, and may be used to bring the work of the physicist and the mathematician into close co-operation.

*Science and Geography.* Simple problems connected with the composition, pressure, temperature, and moisture of the air are usually dealt with in science courses; so also are convection currents in air and in the sea, and variation of the density of water with temperature. It will mutually benefit both subjects if the science and geography masters work in co-operation, so that the use of the thermometer, barometer, rain-gauge, and hygrometer can be really understood.

The science master can help with the description and properties of ores of metals and of common minerals such as limestone, sand, and clay. The biologist can help the geographer to deal

with the distribution of plants and animals, the rise and fall of animal populations, plagues, the control of pests, and of weeds, parasites, and disease. Animal and plant ecology are the concern of both studies.

*Science and Music.* A course in sound which includes reverberation and its correction, resonance in instruments, overtones, and musical scales can be made of special interest to musicians. A gramophone and a simple home-made phonodeik used with vocal and instrumental sounds are useful for demonstrations.

*Science and Art.* The science master deals with colour and the spectrum. Here correlation is desirable lest his teaching and that of the art master may seem to contradict and so leave the pupils in uncertainty.

The art master may give much help in geometrical and mechanical drawing for engineering students as well as in the drawing of diagrams which are so much used to aid verbal description in Science. His work, too, aids biology pupils to record accurately what they see; the close observation of plant forms should be of value in the study of some branches of art.

*Science and Craft Work.* The work of the science and of the crafts departments of a school can be correlated only to a limited extent. The master in charge of wood and metal work has usually a very definite syllabus and scheme of work drawn up with certain definite ends in view, and he cannot very well interrupt the sequence of his lessons to introduce work wanted by other departments. Moreover, boys are not skilled craftsmen, and apparatus made by them is often of little use.

The two departments may, however, be able to help each other in the following ways :—

- (a) If long notice is given so that the work can be put in hand at a convenient time, the woodwork department can furnish boxes for storage, wooden blocks for mounting lenses, electric lamp-holders, ammeters, and voltmeters, screens for photometer and lens work, and "object covers" for lamps for light experiments.
- (b) The woodwork department can sometimes supply more elaborate apparatus, such as working models of pumps.

Boys in science forms should be able to help fit up electric fittings in lamp-stands made in the woodwork room, and in electroplating of beaten metal work.

There are many topics which can be discussed by the science teacher and also by the teachers of craft work. Thus both are concerned with the effects of heat on metals, their expansion, conductivity, and the effects of tempering. There are the chemical effects of ammonia and of potassium dichromate or permanganate when used as stains; the actions of fluxes in soldering and the processes of electroplating.

*Science and Domestic Science.* Here there are many obvious subjects for correlation in thermometry and calorimetry. The melting of fats, the conductivity of fabrics, radiation from rough and from smooth surfaces, ventilation and domestic heating can be studied from the two view-points. The use of electrical apparatus has brought physics teaching into close touch with the home.

#### SPECIMEN SYLLABUSES

Apart from the special reference to syllabuses in Science for sixth form non-specialists in Chapter VI, it is not proposed to include specimen syllabuses in this book. If the reader desires further and more detailed guidance it is suggested that he should refer to the *School Science Review*, No. 95, pp. 96-106 (School Certificate Chemistry); No. 97, pp. 373-379 (Mathematics for Science Specialists), and No. 96, pp. 233-238 (Higher School Certificate Physics and Chemistry), and, of course, to the Science Masters' Association Reports on the teaching of General Science.

#### THE ORGANISATION OF LESSONS

Many good teachers would agree that the following principles form the basis on which lessons should be organised. Such principles must be used with discretion since they cannot always be applied with advantage.

It is important in each lesson to have a definite object in view. The teacher should be clear as to what step forward he expects his pupils to take, and must satisfy himself that they have actually taken it. The lessons, especially if they have not been given before, have to be planned thoroughly and in detail, even if later the teacher finds himself forced to depart from his plan. All necessary apparatus and diagrams should be ready and in good order.

Every lesson needs an introduction, part of which usually consists of a brief revision.

In each lesson, the teacher must keep the method unit in mind, and in the background, the course as a whole. In particular, he must keep in view future applications of the work being done.

The success of a teacher can be measured by the degree to which he stimulates his pupils to interested and purposeful activity. To maintain this activity he will have to see that his pupils understand clearly the purpose of the work and that they have the necessary preliminary knowledge. He must use varied methods and give changes in occupation ; he must keep to the point, avoiding long digressions himself and tactfully suppressing unreasonable ones started by pupils. He must train his pupils to dislike having done for them what they might reasonably expect to do by their own efforts.

It is especially important for the science teacher to beware of parrot-like repetitions of statements and formulæ as a substitute for real understanding of facts, ideas, and principles. He must also remember that understanding comes only gradually and that it is made complete only by repeated application and not merely by verbal repetition. Again, he must remember that the power to use a piece of knowledge comes before the power to express it clearly and with full understanding. Not only do we "learn by doing" but also "we do not truly know how to do a thing until we have actually done it." This last remark applies especially to practical work. Here the teacher should give only the minimum amount of preliminary instruction necessary and let the pupil learn what else he needs as he proceeds. It is worth while to use the special knowledge or ability of individuals for the benefit of others, for one pupil can often help another more effectually than the teacher. It is important to understand the sources of a pupil's difficulties—whether they are in his own mind or in the teacher's exposition.

The average mind deals more readily with concrete than with abstract ideas, for most people think best in terms of things. Hence abstract laws and principles should be constantly connected with actual pieces of apparatus or processes, with models or with diagrams. Such models and diagrams must be designed to illustrate clearly the points at issue. They must not be made more complicated than the case requires. They can often be used to show the pupil what to look for in a piece of apparatus and to guide his understanding of its details.



## SCIENCE AND EVERYDAY LIFE

It is hoped that pupils will learn to think scientifically within the boundaries of the subject they have studied. When faced with problems related to it, they will probably have at any rate some idea of how to start : they will have learned how to word precisely the question they want to put to nature, and what kinds of questions can be put. They will know what kinds of experiments can be done and may have the technique and manipulative skill to carry through these experiments. They will know that the tentative answers they obtain need to be further tested, and will appreciate the sort of adequacy of explanation expected by men of science.

It is by no means certain, however, that even well-taught and intelligent pupils will recognise in everyday life those situations where the scientific mode of approach is appropriate. Nor have we any reason to believe that they will automatically apply to those everyday situations, scientific criteria of adequacy of proof, or that they will be more sensitive to the distinction between fact and prejudiced opinion than people who have been given purely literary training, or that their approach to social problems will always be empirical and pragmatic. Yet it is the development of this attitude and its application to the everyday problems that face citizens which we hope to encourage by our teaching. The pioneers responsible for the introduction of science teaching into our schools hoped with its aid to produce a scientifically-minded generation ; a generation which knew that Science could be a servant to mankind, and knew how it could be made to serve our needs ; a generation whose mental outlook could not prevent it, owing to inherited prejudices, from reaping the fruits of the labours of scientists ; a generation whose habits of thought and intellectual ideals would make it resistant to the wiles of demagogues and advertisers who seek to exploit the weaknesses of their fellows for their own ends. It was obvious to these pioneers that it was neither necessary nor desirable to produce immense numbers of technically trained chemists, physicists, and biologists, but they hoped that the spirit which animates workers in these fields might permeate other regions of human activity. They realised that the fruits of scientific achievement could not be harvested by a people ignorant and contemptuous of scientific ways.

If, then, we are to achieve even partial success in this task

which is so essential to the very survival of human civilisation as we know it, to encourage the diffusion of the scientific mood and temper, we must pay far more attention than has been customary in the past to the methods by which the training we give may be generalised, or transferred to fields not usually thought of as scientific.

### *Transfer of Training*

It has been shown that the spread of the training given in any one subject into other fields does not take place nearly as readily or automatically as was once thought. The study of a particular subject helps us in other fields, chiefly when these have common elements of matter, method, or ideal. Further, active or deliberate transfer is more effective and frequent than passive, automatic, or unintentional transfer : evidently, if we know what it is we want to transfer, we shall be better able to carry out the process. For instance, a person who is consciously aware of the meaning of the scientific mode of approach will be better able to apply it in everyday situations than a person who has merely studied Science without being consciously aware of the generality of the methods he is using.

If a science teacher is to use his opportunities to the full, he will have to pay deliberate attention to these considerations ; that is to say, he will have to teach for transfer. He will have to make his pupils consciously aware of what it is they are trying to transfer, and he will then have to give them examples in other fields (preferably social problems arising in everyday life) where such principles or methods might well be applied.

A simple example may help to make clearer what is meant. Obviously, in any discussion it is important that the terms used shall always mean the same : a true understanding of the need and importance of defining the terms in a discussion will help to make it more fruitful. In science teaching our pupils meet many definitions. Mere knowledge of these definitions is of little use to them unless they become specialists. It would be far more valuable to teach ordinary people how definitions can be constructed, and to show them why scientific terminology is so useful an aid to clear thinking. The acceptance of such a point of view should lead the science teacher to spend more time than is customary on the construction of definitions rather than on merely repeating standard ones. Suppose, for example, that

the pupils have been concerned with the differences between elements and compounds, and that they have carried out a number of experiments involving chemical decomposition and combination. For this work to be done it is not necessary that they should earlier have learned the definitions of the terms "element" and "compound." It is only after the experiments have been carried through that the question of constructing a definition properly arises. The teacher may well begin by listing the differences between substances like chalk or mercuric oxide and others like carbon, copper, or oxygen. He might ask the pupils to suggest a suitable definition. The sort of thing suggested will probably be insufficient and inaccurate, but it should be provisionally accepted, and the correct statement elicited by skilful questioning and criticism. It is still necessary to go on and to show the students that a good definition is one which embraces everything that is included in the meaning of the word and which excludes everything else ; that it must not be mere repetition, and that it must be expressed in clear, simple language. Having reached this stage, it would then be well to proceed to the next and to ask the pupils to construct definitions of non-scientific words. With intelligent and older boys, it would be highly educative to get them to frame definitions of terms like Aryan, Nordic, Communist, Fascist, and to show that the application of scientific criteria to terms of this kind would invalidate many of the loose arguments now in vogue. Work of this kind would not be waste of the periods allotted to Science but would illustrate to the pupils that the work they were being asked to tackle had value outside the classroom.

It is evident that science lessons offer a very fruitful field for this kind of training and that daily papers, advertisements, and popular scientific books give much scope to the teacher of Science who, aware of his social responsibilities, is desirous of enabling his pupils to apply this kind of thinking to their day-to-day activities.

Modern Science is characterised by its spirit of active enquiry ; its empiricism and reliance on experiment and observation rather than on authority and tradition ; its pragmatic outlook, the search for theories that work and are useful rather than for absolute truths.

These characteristics can be introduced into elementary teaching by making a particular series of lessons a simple investiga-

tion of an important problem. The pupils must feel that such problems are genuine, for a task labelled a "problem" by the teacher is not thereby necessarily so accepted by the class.

The pupils are led to state the problem in the form of one or two precise and simply worded questions. One or two possible answers, which occur to the class after thinking over the questions, are taken as hypotheses. Experiments are devised to test them. These are then carried out by the pupils or as demonstrations by the teacher. The observations made are recorded, together with any measurements taken. By inspection of the facts, the pupils can decide which of the hypotheses has been verified, or if necessary new forms of hypothesis can be formulated. A statement can then be made of the conclusions with notes of other questions which seem relevant.

#### THE TEACHING OF SCIENTIFIC METHOD

What we have been considering above is one aspect of what is often called "the teaching of the scientific method." Some teachers are inclined to think that such teaching is something too difficult and recondite for the average adolescent. But to argue in this way is to overlook the fact that the method is itself the result of a long evolution. The complete scientific method of to-day was developed in at least three stages and pupils may well follow the same plan.

The first stage—the contribution of Aristotle and Bacon—is the one with which children should begin. It may be called the Method of Observation. The starting-point should be a clear and simple statement of the problem; the next step, is to examine it in order to find an answer and possibly an application. By using this method of approach pupils may tackle such questions as :—

How many legs has a spider?

Which comes first, the thunder or the lightning?

Are the sunset colours simple colours, as given by a prism?

The second stage, Galileo's contribution, may be called the Method of Trial. Here the procedure would be to make a clear and simple statement of the problem; to examine it; to suggest a possible solution, and to test the solution in order to arrive at a conclusion and possibly an application. This method could be successfully applied to such questions as :—

How can one put out an oil fire?

Does a rabbit's foot bring good luck?

Where stages one and two fail, the third, or "Newtonian" method, may succeed. This may be called the Method of Verifying Deductions. By this method the pupil would begin by collecting all the relevant facts ; he would then suggest possible solutions and choose the most likely one ; predict consequences likely to follow should his solution be correct ; and finally, test his deductions by experiment in order to arrive at a conclusion and possibly an application. In this way\* one could deal with such questions as :—

Why do electric transformers hum ?

How do the points on lightning rods protect buildings ?

#### THE RELATIVE MERITS OF PRACTICAL WORK BY THE PUPILS AND DEMONSTRATIONS BY THE TEACHER

When science teaching was first introduced into the curriculum of secondary schools, it was customary to carry out in front of the boys a number of demonstration experiments. The objects of these were to arouse interest and a feeling of wonder ; to convince the pupils that the statements made by the teacher or lecturer could be verified by sense experience ; to make it easier for the pupils to remember what happened under certain conditions by showing instead of describing, thereby appealing to several senses at once. When carefully carried out, these demonstrations undoubtedly achieved a good measure of success. The series of lectures, adapted for a juvenile audience, given each year at the Royal Institution are an excellent example of the use of demonstrations in science teaching.

Towards the end of the last century much dissatisfaction was felt and expressed with this demonstration technique. Reformers like Armstrong and others urged that Science was something one *did*, and not something one *watched* being done. Their arguments convinced others that more activity should be introduced into the classroom ; they felt, with Aristotle, that one "learns by doing." In consequence, schools were gradually equipped with specially fitted rooms adapted to individual work by pupils and before long teachers of Science became convinced that Science could not be effectively taught unless the pupils spent a large part of their time in manipulating apparatus

\* The teaching of scientific method has been ably discussed by H. E. Armstrong in *The Teaching of Scientific Method*. See also the article by Dr. P. B. Sharpe in *School Science and Mathematics*, 1938, and G. P. Meredith's article in *The Forum of Education*, 1927.

and materials. This represented an undoubted advance in the methods of science teaching, for it has been recognised that many pupils cannot understand without first hand experience, while all pupils learn more readily under these conditions.

Nevertheless, the gain was not always as great as was sometimes thought. The equipment at the disposal of the teacher was not always adequate. The desire for economy led to the inclusion of many experiments which owed their place more to the fact that they required little apparatus than to their intrinsic worth. For example this might be said of many pin methods in optics which were not adapted for teaching beginners the fundamental principles of the subject in a simple and direct manner.

The doubts as to the efficacy of the individual work done in school laboratories led to a large number of researches which attempted to measure the success of the individual and demonstration methods of experimentation. Indeed, this part of the theory of science teaching has possibly been more thoroughly explored than any other. As a general rule, the investigators have taught two parallel classes of equal ability. One of these is allowed to do the experimental work individually, the other is taught purely by demonstration methods. At the end of, say, six months, the two classes are given tests which attempt to measure the extent to which they have learned new facts or laws, or have mastered the principles involved. Sometimes a further period of six months or a year is allowed to elapse, and a further test is given to see which method is more effective in instilling permanent knowledge. In some ways these experiments have been quite inconclusive, in others they have been quite conclusive. Thus they do not prove that either method is definitely superior to the other: the differences in the scores never amount to more than a few per cent. of the total marks. There appears to be little doubt that the "demonstration" pupils as a whole score rather higher marks on the immediate tests, while the "individual" pupils score rather more on the delayed tests. But it should be emphasised that the differences in the scores are very small. Moreover, individuals differ, some learning better from demonstrations and some from practical work. It may thus be said that these experiments prove conclusively that neither method is definitely so superior to the other in teaching all aspects of Science as to force us to use it to the exclusion of the other.

### DEMONSTRATION TECHNIQUE

Each teacher has to evolve a technique suitable to the resources of his own laboratory if his demonstrations are to drive home the points they are intended to illustrate. The young teacher should ask himself how the demonstration he thinks of using will help his pupils, and how he can make the class participate actively while the demonstration is being given.

Fowles (*Lecture Experiments in Chemistry*) makes the following suggestions :—

- (1) The apparatus should be ready before the class assembles.
- (2) New experiments should be tried over beforehand.
- (3) A reserve of spare parts for the apparatus should be on the bench.
- (4) If an experiment fails it is inadvisable to seek the cause unless the class is well in hand, when the search is profitable.
- (5) If a sequence of experiments is intended, it is advisable to follow the advice of Faraday and arrange them on the lecture bench in the order in which they will be performed.
- (6) Get promising members of the class to help with the experiments.

The problems of discipline are often very real while the demonstration is in progress, until the beginner has learnt how to keep the class busy so that the pupils take an active part in the work, and draw diagrams and write up notes during any pauses in his experiments.

There are many differences of opinion about the way in which pupils should write up accounts of class work. Most teachers think it unwise to dictate notes except to beginners, though exactly worded laws and definitions have to be so given. A good deal of help has to be offered during the first year of a science course, but later the pupils are usually able to make their own records as supplements to the text-book they are using. The subject is discussed at some length in *Lecture Experiments in Chemistry* (Fowles), *Science Teaching* (Westaway), and *Hints on Notemaking in Science and Mathematics* (Hughes).

### LABORATORY WORK

Practical work in the laboratory should be related carefully to the mental age of the pupil, and much time can be saved if

essential points of laboratory technique are taught to a class as soon as they begin experimental work in which the particular skill will be required.

Most teachers let qualitative work in a subject precede measurement and attempt in the early stages to keep the quantitative work small in amount and confined to essentials. It is well to consider what is the highest degree of accuracy of measurement which may be expected from a particular class and to avoid slow and cumbrous methods when a reasonable accuracy can be obtained by quicker ones. Thus for many experiments the slowness of weighing by the beam balance can be avoided in elementary physical work, by using larger quantities of material and modern balances which dispense with small weights. The use of beams of light in place of pins saves much time in optical experiments, and there seems to be a case for reduction in the amount of quantitative work traditionally done in elementary chemistry.

Methods of giving instructions before the pupils begin their laboratory work vary widely. The pupil must understand exactly what is the object of his experiment but he must not be told too much. He will have to be told about what quantities of material he should use and will often have to know for what he has to look without being told just what he will see.

Some teachers prefer to give oral instructions or notes on a blackboard, particularly when all the class are to do exactly the same experiment. The use of duplicated sheets or of a practical text-book is helpful when various experiments are being carried out and when the pupils work at very different speeds. In the first two or three years of the course this method has the danger that unless the instructions are very skilfully worded they may eliminate all the essential thinking and leave the pupils only the manipulation. Pupils can spend hours following sheets of instructions without learning much Science, just as those who make up radio sets from blueprints often do so without learning much about electricity.

In elementary classes it is usual for the pupils to work in pairs, partly to economise space and material and partly because many experiments are beyond the manipulative powers of a beginner. The teacher then has to do his best to prevent one pupil doing all the thinking and most of the work while the other jots down the records. With groups of three or more doing one experiment the



difficulty is acute. For the last year of the School Certificate course and for all advanced work it is a great advantage if the greater part of the work can be done by an individual.

The issue of apparatus needs forethought and organisation. When suitable accommodation is available, it is often convenient to allot a set of simple apparatus to each working place and make the pupils who work there responsible for its good condition. This apparatus can best be stored under the benches in cupboards or on shelves. Many teachers find it simpler to have the requisite sets of apparatus stored in trays or other containers so that all the essentials can be put out in very short time. When a laboratory assistant is available he will see that such apparatus is put out and collected ; if not, selected pupils can be detailed for this work which, if carefully arranged, will waste very little time.

Discipline in a laboratory is much simplified if movement about the room is reduced as much as possible. The pupils must also be made to understand that conversation when necessary between those who are working together must be restricted to matters relevant to the work being done. The safety of the pupil and the freedom of the teacher from legal liabilities demand that unauthorised experiments shall not be attempted. The certainty of detection by an alert teacher is the most effective deterrent !

Much valuable teaching is done while practical work is going on, for the teacher is giving attention to individuals, explaining difficult ideas and asking questions. It is often possible towards the end of the period, to review the results obtained by a class and show the likely accuracy of observations or measurements. Questions then show if the work has been understood and whether any generalisation can be stated from the results obtained.

Many teachers feel that valuable opportunities of training would be lost if, at the end of a laboratory period, the pupils did not themselves clear up their own benches and leave their apparatus reasonably clean and tidy.

*Laboratory Notes.* It is usual to expect pupils to write up an account of every experiment they do. The account should include a clear statement of the object of the experiment and a description of how the apparatus for it is set up and used, with sectional diagrams. All results should be recorded as they are taken and a clear statement made of the results obtained and of any deduction made from them.

Laboratory records made in this way form a valuable part of scientific training besides giving practice in the writing of clear English. Abbreviations must be kept within reasonable bounds and pupils should be taught what are the conventional and legitimate uses of chemical formulæ.

*Laboratory Rules.* Every laboratory should have posted in it a list of rules to be observed. A typical set of such rules will be found on p. 120.

### THE USE OF TEXT-BOOKS

There is general agreement that no text-book is necessary at the very beginning of the course. Later practice varies from school to school. Elementary books can usually be classed roughly into the "readable," the "logical," and the "revision" types, and for the second and third years of a secondary school course many science masters prefer the "readable." In the year preceding the School Certificate examination the "logical" type is often used. Many teachers dislike and condemn a "revision" book as having little value from the point of view of scientific training; others say that it gives the essentials which must eventually be committed to memory and helps especially pupils who through illness have missed some part of the course.

Most teachers prefer to shape their own syllabus and use a book as a supplement for private reading, preparation and revision. They also seem not to want details of laboratory work to be included in ordinary books, probably because the apparatus in each laboratory makes standardised instructions less effective.

### REVISION AND TESTS

Every experienced teacher knows the necessity for repeated testing and revision of earlier work. The usual methods by short oral or written answers can be used to check prepared work. The ordinary type of "essay" question gives practice in the organisation of memorised facts while many of the new type tests show, with the minimum of time spent on testing and correcting, which pupils have acquired a satisfactory knowledge of the work done. The small allotment of time in many schools makes it difficult to allow adequate time for revision and this bears most hardly on the slower pupils who need to work over a subject several times before they understand it.

## HOMEWORK

As a general rule, the time allotted for science homework every week is utilised by teachers to give their pupils an opportunity to master and to learn thoroughly the material dealt with during their lessons. Thus, written exercises may be set, or the pupils may be directed to read selected portions of book work carefully, or they may be instructed to write out in detail a record of the experiments previously carried out in the laboratory or the rough notes taken down during the lesson. Work of this sort is valuable, but it is by no means certain that it represents the best kind of homework, or out-of-school work, for this kind of work can often be done just as well in the classroom where one can be sure the pupils will be undisturbed for the requisite length of time.

It might be found more profitable not to set as homework any work that could be more easily done in school, and to set aside in school definite periods for individual study, for reading and writing.

This can only be done in schools where really adequate time is given to Science. It is then possible to give as homework, investigations of everyday things such as the following :—

Examine the gas or electric cooker employed in your home and write a report on the methods taken by the manufacturer to diminish unnecessary loss of heat.

Examine the hot-water system in your home and draw a plan of the pipes.

Look round your home and make a list of metal objects which have been plated with another metal. On your list mark with "E" those which have been electroplated.

Find out from the fishmonger where he gets (a) mackerel, (b) cod, and at what season of the year these fish are easiest to obtain.

Cut open a mackerel or herring and make a drawing of the skeleton of the fish.

Find a thrush's nest and describe what it looks like and the colour and marking of the eggs.

## MARKING

The individual work of pupils must be looked at by the teacher and corrected. On this task of examining the pupils' notes and

records, conscientious teachers spend an enormous amount of time. Indeed, it may become so heavy a burden on teachers that too little time is left in which to read new books and to keep abreast of the newer developments in their own subject. In that case their efficiency as teachers is being diminished by their devotion to their everyday tasks, for only the man who is continually stimulated by contact with new ideas can continue to stimulate his own pupils with a love of Science. It is important, therefore, that time in marking be saved in every possible way. It is suggested that teachers will find it convenient to introduce a code, understood by all their pupils. For instance, mistakes in English could be pointed out by writing "E" in the margin of the pupil's book; mistakes of fact by writing "F"; mistakes in spelling by writing "S"; "C" might mean "Come and see me."\* Such a system will not only save time now spent in writing corrections, but would have the further advantage of inducing pupils to correct their own mistakes. Some prominent teachers and at least one well-known former inspector of schools† have suggested that pupils' notes and records need only be marked about every half term. Though the idea at the back of this suggestion may be sound, yet in practice it is often impracticable. The amount of work piled up is so great that the teacher cannot find time to mark it properly.

A record of the marks obtained by the pupils should be kept so that their progress may be watched, and so that terminal reports may have validity and reliability.

There is one simple way in which experimental psychology may be used by teachers. There are now available many different intelligence tests which may be used to determine the intelligence quotients of the members of a class. (It need scarcely be added that these should be kept secret and that no pupil should know either his own or any other pupil's I.Q.) The class should then be arranged in order of decreasing I.Q. A similar list is drawn up showing terminal marks; a graph is then drawn placing pupils' I.Q. order along one axis and terminal order along the other. The position of individual pupils will then be seen by points on the graph (see diagram).

It will usually be noted that the position of most pupils falls

\* It is helpful if this code corresponds as far as possible with that adopted by English teachers in the same school.

† See *Science Teaching*, by F. W. Westaway.

near the diagonal. For these the class order is about what one would expect from their intelligence. But consider N: he comes much higher in the class order than one would expect from his I.Q. The inference is that either the intelligence test has not properly measured his ability, or that he is a very hard worker, or that he is driven on and helped at home. Consider M. Judging from the measured I.Q., one would expect him to do much better work. Therefore, either the intelligence test has not properly measured ability, or some factor is preventing

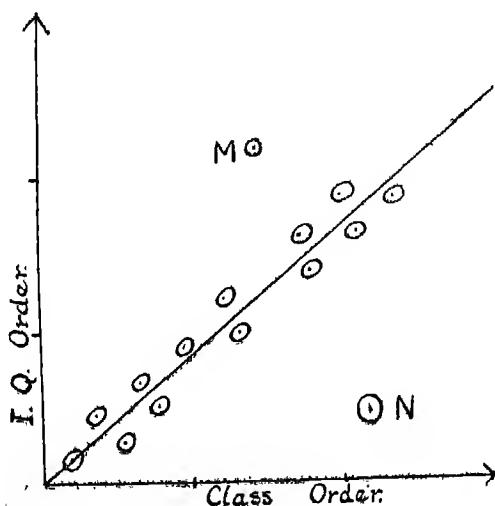


Figure 31.—Graph of Class Order and I.Q. Order

him from working as well as he could. The teacher will find it more profitable to investigate carefully the reason for the comparative failure of such a pupil as M. than to pick haphazard. Often it will be found that emotional difficulties or problems at home are responsible for comparative failure. Encouragement and sympathy may often make a remarkable difference to the quality of the work sent in by such pupils.

#### PRIVATE STUDY

Very few schools are able to make much use of private study for science work in the pre-School Certificate years. The time allotted to Science is already meagre and if a reasonable amount of ground is to be covered the greater part of this time has to be

taken up by organised teaching. Moreover, the majority of teachers have grave doubts as to the benefits derived from private study at this stage unless it is very closely supervised. On the other hand, there is no question that Science benefits from wide reading and a wide background of knowledge. If close guidance and supervision can be given, time devoted to private study in the last two years of the School Certificate Course may be valuable.

In the post-School Certificate forms it is essential that there should be time for private study. The pupils must be encouraged to read widely and to get to know how to use a science library to the best advantage.

#### USE OF BOOKS AND LIBRARIES

A teacher's success should be measured more by the habits and skills developed by his pupils and applied after they have left school than by the marks and examination successes they secure while at school. A good teacher will endeavour to train his pupils to make use of books and reference libraries, and will train them to obtain knowledge for themselves rather than encourage them always to rely upon his instructions. There should be attached to every laboratory a library of books suitable for reference purposes and for reading by young people. "A List of Books Suitable for a School Science Library," published by the Science Masters' Association, will be found very useful. Whenever necessary, the teacher should send pupils to consult the books in the science library. In addition, students should be set tasks calling for reference to books in the school library or in a public library.

## CHAPTER VI

### ADVANCED COURSE WORK

#### *The History of the Higher School Certificate Examination*

At the end of the nineteenth century, sixth form work in secondary schools was mainly concerned with those pupils who were hoping, with the assistance of a scholarship, to proceed to a university, preferably to one of the older universities. The work done was based upon the requirements of the open scholarships at Oxford and Cambridge, and was therefore of a highly specialised character. Intensive preparation often began at an early age. Classics and Mathematics held pre-eminent places in the curriculum, but the claims of Science, of Modern Languages, and of modern studies in general were becoming more widely recognised.

Sixth forms were small and consisted generally of pupils of outstanding ability, capable of doing advanced, specialised work. The Oxford Delegacy, the Cambridge Local Examinations Syndicate, and the Oxford and Cambridge Joint Board, had established higher examinations intended for pupils from 18 to 19 years of age and based upon the requirements of the open scholarships. The Oxford and Cambridge Joint Board catered for the majority of the candidates.

It should, however, be noted that many of the secondary schools in the London area were beginning to prepare pupils for the Intermediate Examinations in Arts and Science of the University of London, taking these examinations rather than the "Higher Examination" of that university.

The Education Act of 1902 brought into existence secondary schools established and maintained by local education authorities and rendered possible a revival and expansion of many of the old grammar schools, which were able, for the first time, to receive substantial aid from local public funds. The resulting increase in the number of secondary school pupils was accompanied by the taking of many more examinations. This created great difficulties in school organisation.

The problem was referred to the Consultative Committee of the Board of Education, which in 1911 issued a "Report on Examinations in Secondary Schools." In accord with the findings of this report, the Board of Education issued regulations recognising two external examinations for pupils of secondary schools :

- (a) a First School or School Certificate Examination for pupils at the age of 16 years to 16 years 8 months ;
- (b) a Second School or Higher School Certificate Examination for pupils who had followed a two years' course subsequent to the First School Examination.

This Second Examination, commonly known as the Higher School Certificate Examination, was to be upon three main subjects of a common or allied nature, together with one subject, from any group, at a lower standard, taken in a more general or less intensive manner.

The Board of Education proceeded to recognise the Higher School Certificate Examinations of various examining bodies and finally recognised those of the eight examining boards of England and Wales. Although the syllabuses and standards of these examinations varied to some extent, they were all based upon the Higher Examinations of the Oxford and Cambridge Joint Board and of the Oxford and Cambridge Locals, i.e., upon a standard suitable for and intended for prospective university scholars.

The extent of sixth-form work was enormously increased by the establishment, in 1918, of advanced courses and the payment of special grants for these courses. The resulting expansion may be seen from the fact that whereas in 1908 about 3,500 candidates took the Higher Examination, in 1935 there were no fewer than 11,375 candidates for the various Higher School Certificate Examinations. This period of expansion has also seen a large increase in the number of scholarships tenable at the universities. In addition to state scholarships, the number of which has been successively increased from 200 to 300, and then to 360, many scholarships are awarded by local education authorities.

State and L.E.A. Scholarships are now awarded upon the results of the Higher School Certificate Examinations. In consequence these examinations have assumed to a growing extent a competitive character. Thus the Higher School Certificate Examination is called upon to fulfil simultaneously two separate purposes : (a) to serve as a qualifying test, and (b) to



select scholars. Hence the work of a large number of candidates, whose interests would be better served by preparation for a qualifying examination of a less specialised character, is now tested by a highly specialised examination. Under these conditions, serious doubts are felt as to whether the courses leading to the examination fulfil their purpose.

The lack of uniformity in the regulations of the several examining boards introduces serious difficulties in comparing the performances of candidates who take the different examinations. Thus very grave doubts have arisen as to the equitable award of state and other scholarships, and these doubts are intensified by the knowledge that different examining boards award the scholarships on different principles.

These defects have been widely recognised, and several examining boards have revised their regulations in an endeavour to make their Higher School Certificate Examinations serve both the purposes referred to. For example, some boards have introduced special scholarship papers of a higher standard than the ordinary papers, to be taken only by candidates for scholarships. Others have experimented with variants of a "points" system which also enables non-scholarship candidates to avoid taking subjects to scholarship standard. It is widely felt, however, that the objective of making one examination suitable for the two purposes is not easily reached, and that it is doubtful whether a single examination can provide the necessary stimulus and test for those capable of and ambitious for university honours without producing undue pressure upon the average pupils. It is interesting to notice in this connection that all the four secondary associations agree that separate scholarship papers at least are essential. After a full and lengthy enquiry the Norwood Committee advocated the complete separation of scholarship awards from the Higher School Certificate Examination and the setting up of a new Scholarship Examination. This suggestion would probably meet with a very large measure of approval if the universities and university colleges were prepared to award their open scholarships also on the results of the new examination, but this is unlikely. Consequently, such an examination would add one more to the already unduly large number of examinations likely to be taken by advanced course pupils. For this reason alone the recommendation has been strongly opposed in many quarters.

*The Higher School Certificate Course*

## (1) AIMS OF THE COURSE

When pupils have gained a School Certificate, some change in attitude towards school work is to be anticipated. They have reached an age when they may be expected to have developed special interests and to display individual aptitudes. In general, they will require from their studies in the years following the School Certificate stage, results of definitely vocational value and importance. Some desire at the end of these years to leave school with qualifications which will secure their entry into some specialised form of professional work or of industry. Others intend to proceed to a university or to some other institution for higher education and to enter for scholarship or other competitive examinations. It seems that the Higher Certificate course should primarily cater for special interests and aptitudes and at the same time provide for certain vocational requirements.

The ideal course at the Higher School Certificate stage will be one in which habits of thought and outlook associated with both scientific and other kinds of knowledge are developed and strengthened. The special interests, aptitudes, and requirements of the pupils will be catered for by the specialised study of a group of cognate subjects to which, justifiably, the greater part of the time available for study will be devoted. If, however, the courses do not bring the pupils into contact with both scientific and other methods of thought they will not form a satisfactory preparation for life. Thus the specialised work of those pupils who choose a Higher School Certificate course in Science should be supplemented by a range of non-scientific studies. For pupils whose chief work lies in other subjects, the inclusion of some obligatory Science is essential. The Science course for students of other subjects should give the pupils a comprehensive, though of necessity not an exhaustive, view of scientific knowledge. Thus the ideal course should include some studies both of animate and of inanimate matter.

## (2) DEFECTS OF PRESENT COURSES

The present Higher Certificate courses appear to possess a number of unsatisfactory features. In the first place, the Higher Certificate is awarded as a result of success in an examination in a very small number of subjects. In most cases two or three main

subjects suffice, the precise requirements depending upon the regulations of the particular examining body. Such a small number of subjects cannot possibly satisfy the ideals set forth above.

It is true that pupils in schools controlled by the Ministry of Education are compelled to spend a number of periods each week on subjects which are often referred to as "cultural." We would point out that science subjects are also cultural and would stress again the importance of including in every Higher Certificate Course some scientific and some non-scientific studies. The exact proportions in which these are introduced will depend upon the aptitudes and interests of the pupils.

The value of the "complementary" subjects under present conditions is liable to be very small. They are not examination subjects and this fact often results in lack of interest and of industry on the part of the pupils during the periods devoted to their study.

Success in the Higher Certificate Examination is, in certain cases, a method of securing exemption from parts or from the whole of the intermediate and other examinations.\* Subjects which do not give such exemption assume less importance in the eyes of many pupils, and those which do are given a relative importance which cannot always be justified. A scale of values based so manifestly on immediately utilitarian grounds tends to affect adversely the work done in certain subjects and the general outlook of the pupils in after life.

There is a wide divergence between the requirements of the different examining bodies. During the actual school course this matters little to the majority of the pupils of any individual school, which is seldom concerned with more than one such body. But pupils from different schools meet in scholarship competitions and in universities and similar institutions. It seems possible that divergent regulations will handicap certain

\* Under London University regulations, complete exemption from Intermediate B.Sc. can at present be obtained by reaching an adequate standard in four main subjects, though only three at most are required for the Higher Certificate. The result is that the majority of pupils taking the London Examination offer four main subjects. These pupils have only the same time at their disposal as pupils examined under Examining Boards have for three. The standard required at London does not appear to be lower than elsewhere. There is danger therefore, where schools allow their pupils to seek exemption from the London Intermediate Examination, that the education of these students may suffer. The school authorities are tempted to let such pupils drop the complementary subjects in order to make time for the additional specialist work. Notice of a change in the exemption regulations has just been given.

pupils in competition, and that the lack of a common starting point in the university affects some of the pupils adversely. This has been widely recognised and a conference of representatives of the teachers and the universities at Cambridge has called for a greater degree of uniformity in the requirements of the various examining boards.

Many of the present regulations still appear to be framed on the assumption that all the pupils taking the Higher School Certificate Examination are intending to become university students. For those who will eventually do university work the system is probably satisfactory, but it appears desirable that provision should be made for pupils who have no intention of taking university degrees. This has been done by some examining boards. Their methods of tackling the problem differ, but usually directly or indirectly they abolish the system of "groups" for those pupils.

The connection which has sprung up between the Higher School Certificate examinations and the award of state and other scholarships has conferred on the examination a competitive character which is very different from what is required and from what was originally intended, viz. : an assessment of the work done in the Higher Certificate Course.

It seems desirable, then, that :

(a) The Higher School Certificate should become concerned with a larger and more diverse range of subjects than at present. It must not, however, be altered in any way that involves undue pressure on the pupils.

(b) The requirements of the various examinations should be made more nearly uniform.

(c) Some form of standardisation of the method of obtaining exemption from university and professional examinations is necessary.

(d) Competitive characteristics of the examination should be eliminated as far as possible.

(e) Further consideration should be given to the question whether the present specialised courses are satisfactory for pupils who do not intend to pursue university courses.

### (3) SOME SPECIAL CONSIDERATIONS

It has been mentioned that there is a very widespread, and very natural tendency for work in unexamined subjects to suffer through lack of enthusiasm and industry on the part of the

pupils. Everything possible should be done to encourage work in these subjects, so that they will be regarded as important and treated as seriously as subjects which are offered for examination.

As long as there is a direct connection between the Higher Certificate and the various university examinations, the universities will justifiably claim the right of making whatever conditions seem appropriate to themselves. A severance of the direct connection, therefore, seems imperative if standardisation of examination requirements is desired.

In science courses it should be noted that

- (a) The general trend of educational progress in the schools is towards greater breadth ;
- (b) a large number of the pupils who pass on to the universities will eventually have to read four subjects ;
- (c) it is desirable that courses should include both physical and biological science ;
- (d) for graduate teachers there is a considerable number of openings for those who can teach three or even four subjects. Pupils (especially those who are not reasonably certain of high honours in their degree examinations) may be better advised to embark on a course comprising a lower standard in a larger range of subjects (as in the General Honours Examinations of some universities) than to specialise in a single subject. School courses should make both alternatives practicable ;
- (e) in industry, scientific qualifications in certain combinations of subjects appear to be very desirable. A physicist or a chemist must have an adequate knowledge of mathematics ; a biologist must have sufficient acquaintance with chemistry and needs some knowledge of mathematics ; it is often useful for a chemist or a physicist to have some knowledge of biology.

Some form of external examination appears inevitable for years to come. The existence of external examinations and externally drafted syllabuses implies an externally imposed standard for success and to some extent an externally imposed standard of treatment. This must result in some curtailment of individuality in the selection and treatment of subject matter. The desirability of freedom must be reconciled with the equal desirability of the standardisation of examination requirements ;

the objective must be to preserve the maximum practicable degree of freedom.

In framing mathematics syllabuses for science students their special requirements should be kept in mind. To the scientist, mathematics is a necessary piece of equipment without which he cannot carry on certain branches of his work. Much of the mathematics at present taught in science courses is, *from this point of view*, of doubtful value to science students and might well be omitted, while other topics might receive more attention. Graphical work, degree of accuracy, approximate methods, the elements of statistics and of vector algebra are becoming increasingly valuable to science students. Doubtless topics of this kind could be used just as well as others in order to demonstrate to pupils the nature of mathematical thinking.

The system by which at present Mathematics, as Pure Mathematics and Applied Mathematics, can figure as two subjects offered by science candidates also needs consideration. It is a matter for discussion whether, if a science course consists of four special subjects, one half of these should be mathematics. A course comprising three subjects only, of which two are mathematics, is obviously a mathematics course, and is mainly the concern of the mathematicians.

It may be pointed out that the retention of Pure and Applied Mathematics allows pupils to defer their final decision whether to specialise in Mathematics or Science for two years. Whether this is desirable is a matter upon which opinions differ.

### RECOMMENDATIONS

The Committee recommend that :—

(1) The usual qualification for entrance upon a Degree Course from a secondary grammar school should be the possession of a School Certificate together with some measure of success in a Higher School Certificate examination.

(2) No scholarship awards should be made upon the results of the ordinary Higher School Certificate examination. If the machinery of that examination must be used, additional papers should be set and only *bona fide* scholarship candidates should be allowed to take them.

(3) The work in the Higher Certificate course should be regarded as falling into two categories, viz. : studies included mainly for vocational considerations and studies included largely for their

cultural value. Since vocational studies should also be cultural, it seems preferable to term the two categories, main subjects and complementary subjects.

(4) In a science course the main subjects should be submitted for external examination and should be controlled by defined syllabuses. The study of the complementary subjects is of great value to the pupils. These subjects need not be submitted for external examination, and the choice of their subject matter and of its treatment should be at the discretion of individual schools. One-third of the school time should be allotted and used for the study of these complementary subjects.

(5) The Higher Certificate awarded should record the passing of the examination in the requisite number of main subjects and the satisfactory completion of a course in the complementary subjects.

(6) (a) There is a considerable difference of opinion as to the number of subjects in which a pass should be required to obtain a Higher School Certificate. The majority of the Committee favour three main subjects, the syllabus in each subject to be less than at present. The choice of subjects will be determined by the tastes and abilities of the candidates. As many pupils whose future does not lie in university studies will desire a wider choice of subjects than is permitted by the regulations of some boards it is felt that it would be better to abolish all groupings of subjects. Moreover, in suggesting three main subjects it is not intended to prevent such combinations as two main plus two subsidiary or one main plus four subsidiary subjects. Science candidates who intend to continue their studies to the standard of a university degree will be well advised to select all their main subjects from the following :—

Chemistry, Physics, Pure Mathematics, Applied Mathematics,  
Biology, Mathematics (composite syllabus), Botany, Zoology,  
Geology.

(b) Pupils should be advised to study complementary subjects selected from the following :—

- (i) English and social studies, such as certain aspects of History, Geography, Civics, Economics, Social Biology (if some form of Biology is not taken as a main subject), and possibly Scripture.
- (ii) Foreign languages (either modern or classical).
- (iii) Art, Music, Craftsmanship.

(c) Two-thirds of the available time should be given to main subjects; the remainder to complementary subjects and to Physical Training.

(d) It is felt that corresponding schemes should be adopted in all Higher Certificate courses. For courses other than those in Science the complementary subjects should include some obligatory Science.

### *Methods in the Higher School Certificate Course*

Sixth-form pupils are the survivors of a process of elimination; they are relatively few in number and for a period of two or three years will remain at school, occupying positions of authority and exerting important influence as school captains and prefects. Further, as potential leaders of thought and conduct in a larger world, the interest of these pupils will be best served by a training which fits them for leadership. Direction, advice, and constructive criticism will constitute in large measure the activity of the sixth-form teacher. The work of the science sixth will be carried on by means of lecture lessons, discussions, private study, and laboratory work.

### THE LECTURE LESSON

Naturally the sixth-form lessons will differ in plan and presentation from those given to junior pupils. Facts and topics well treated in the text-books can now be left for the pupils themselves to study, leaving the teacher free to inculcate principles whose mastery generally require apt illustration and repeated exposition.

### DISCUSSION

Discussion reveals variety in the approach of different minds to the same subject matter and individual difficulties are brought to light. Initiative is largely with the pupils while the teacher seeks to direct and to stimulate. The method has its dangers, for it is easy to develop a habit of mind in which the individual relies too much on external stimulation and suggestion. The method will clearly fail unless for the individual pupils there is a gain of positive knowledge and the formulation of definite conclusions. This must, from time to time, be checked by written work.

### PRIVATE STUDY

For pupils about to commence their sixth-form studies it is essential to devote preliminary attention to a further development



of the art of private study. To this end a lesson on the use of textbooks, reference books, and the library may well be followed by a discussion in which a summary is formulated for some selected item of subject matter. Attention would be directed to the selection of essentials, their logical arrangement, and the need for brevity. Much may be learnt by noting the common ground and the points of difference in the presentation of the same subject matter in different books. A note of any difficulty encountered is essential in order that such difficulties may be dealt with later in class. Exercises in writing summaries should be given. For initial attempts, suitable paragraph headings might be supplied while selected examples of such exercises might later provide material for discussion. Pupils encouraged by some preliminary practice should rapidly gain in confidence and skill and find themselves able to carry on successfully their own private study. It is clear that such work implies access to adequate text and reference books and the use of a well-stocked library. Here lies the importance of care and wisdom in the choice of such books. Much valuable assistance is available in the reviews of new publications appearing in the "A.M.A." and *School Science Review*, and in the pamphlet "A List of Books Suitable for a School Science Library," published by the Science Masters' Association.

### LABORATORY WORK

Laboratory work is of great importance and in its performance the pupil's earlier experience in method and manipulation entitles him to a considerable degree of liberty, though it is clear that some supervision by the teacher is essential so that his greater experience shall be at the service of the pupils. The most valuable service the teacher can render will come from his personal interest for the work in hand. An occasional enquiry as to progress and a brief discussion of any difficulties or points of special interest may contribute much to keenness and enthusiasm in the pupil. Help in difficulties may be offered in the form of suggestion rather than of complete solution.

The laboratory course itself will be based on a series of experiments drawn up by the teacher to exhibit fundamental principles and measurements. This course should be available to the pupils and should include alternative experiments. Some choice is then possible while the pupils working as individuals

make progress according to their ability and keenness. Opportunity should be given to pupils who have completed the basic course to investigate points of special interest to themselves. In the third year pupils may well undertake a considerable investigation requiring several weeks' work. Laboratory work should not inevitably be associated with certain "double periods" but rather should be undertaken at the discretion of the teacher. Further, whenever conditions allow, the sixth-form pupil should have access to the laboratory as he feels the need, provided that adequate arrangements for supervision can be made.

It is essential that the pupil should have a clear grasp of the purpose of his work; thus preparatory study is necessary and here a good practical text-book or typed outlines of experiments will find their use. Whenever possible, responsibility for the assembly and the dismantling of apparatus should be taken by the pupils, who should have free access to routine apparatus. In practical work involving measurements, note will be taken of the degree of accuracy obtainable with the apparatus and hence of the reliable figures in the result.

Laboratory records will, from time to time, be discussed with the pupils concerned. The records should be characterised by the inclusion of all measurements and other essential records, and by orderliness and definiteness of statement and conclusion. Notes on precautions necessary for accuracy should be included.

Such matters as the nature and limitations of human knowledge, the growth of scientific knowledge and its value for human welfare should form part of an advanced course in Science. These ideas may be discussed in special lessons or may form part of the work of a Science Society.

### *Organisation*

In schools where accommodation, staffing, equipment, and finance make it possible there should be a separation of the Higher School Certificate classes into distinct units. The first year pupils need the full attention of a teacher for they are young and inexperienced enough to require much formal instruction. They need careful guidance in the methods of private study and in their practical work. Their written work will probably call for lengthy and detailed criticism. Small classes are imperative.

Where possible it is very desirable that there should be labora-

tories reserved entirely for the use of the sixth form for each of the subjects studied in the course. Apparatus must be left without risk of damage or interference and lengthy experiments carried out without causing disturbance to other classes. It is also most helpful if sixth-form pupils can have access to the laboratories whenever necessary, though if pupils are allowed to carry on practical work in their own time the question of the legal responsibility of the teacher in case of accidents is one which must be carefully borne in mind. Individual teachers must decide for themselves the extent to which they are justified (legally and otherwise) in permitting or encouraging such work in the laboratory. In a number of schools this problem may become less difficult if the services of a competent and trustworthy laboratory assistant can be utilised, though the question of legal responsibility will still remain.

Adequate provision should be available for private reading which is free from distraction. Free access to a well-stocked science library is of the utmost value and the possession of such a library is a necessity in all schools where Higher School Certificate work is done. In the larger towns where there are efficient municipal libraries much benefit may result from the use of these. It is recommended that encouragement should be given to pupils to make use of such libraries.

#### COMPOSITE SIXTH FORMS

The ideals stated above make demands on accommodation, staffing, and equipment which many schools cannot, at present, meet since separate laboratories reserved for each Higher School Certificate course are not available. In such schools great difficulties in the organisation of the science teaching are inevitable unless at least one laboratory can be reserved for the sixth form. This should be so laid out that apparatus can be set up and left free from interference.

To some extent deficiencies in apparatus can be remedied by the use of home-made or improvised apparatus. Indeed, apart from any question of deficiencies, the possession of efficient home-made apparatus always lends distinction to the laboratory. Advanced pupils should be encouraged to make apparatus for their own experiments.

The most serious problems arise where for reasons either of accommodation or of staffing, it is impossible to treat the two

years as separate units. Then the whole sixth form must work at the same time at the same subject under the same teacher.

The pupils will inevitably be adversely affected if the classes are too large. Experience suggests that such a composite sixth form should never contain more than 12 pupils ; provided the class does not exceed this size the problem, though formidable, is not insoluble.

Success is achieved in a number of schools as follows. It is possible to deliver a considerable number of formal lessons to the whole form. The difficulties of presentation to pupils at two very distinct stages of proficiency are overcome by short supplementary lessons to the two years separately. Some teachers find it helpful and practicable to have two distinct programmes and to use these in alternate years ; Electricity is studied one year, and Heat, etc., the next. This method is comparatively simple in Physics and perhaps in Biology ; it is also employed by some teachers for Chemistry.

A very definite and clearly defined scheme of private study plays an important part from the earliest stages of the course. Sometimes practical work is carried on by one year while the teacher is taking the other for theoretical work in the laboratory. Some teachers feel that the less close supervision of the practical work may be compensated for by very precise preparation and discussion before such work is undertaken, and by further discussion when it is over. Oral discussion must to some extent be replaced by more detailed written work and by more copious written criticisms by the teacher on the scripts.

Some modification of the "Dalton plan" is likely to be particularly valuable and productive of good results if there are well planned assignments. The success of the method depends upon a well understood contract when the assignment is first allotted.

Lastly, it seems that the content of the syllabuses, and the standards demanded, should not be determined from a consideration of what can be achieved by schools in which conditions are unusually favourable, but from what can be achieved by schools which work under normal conditions.

## SYLLABUSES

In a previous section reasons have been stated for the conviction that some standardisation of regulations for the various Higher

School Certificate examinations is necessary, and at least approximate uniformity of syllabuses. A most useful lead in this direction has been given by the publication of the new Cambridge Advisory Board Syllabuses. It is hoped that these syllabuses, drawn up by committees of experienced teachers and university tutors, will prove a satisfactory basis on which all the examining boards can work. They closely follow the syllabuses put forward by the Science Masters' Association and are certainly a great improvement on many of the existing Higher School Certificate examination syllabuses.

In determining syllabuses, two main factors should be considered. One is the capability of the average pupil. The other is that ample scope should remain for individuality and freedom in the treatment of the subject matter, and for the inclusion of additional topics which individual teachers may wish to include for the purposes of school study.

It is suggested that at present two other factors assume undue importance, viz. the capabilities of the best pupils, and the desires of the universities. It is unsatisfactory and unfair that demands on average pupils should be determined by the capacity of the best. The universities tend to impose standards which are unreasonably high and limit the freedom which is essential to the school.

The syllabuses should be within the reach of the average sixth-form pupil. Pupils who are engaged on Higher School Certificate courses are pupils who have already gained the School Certificate and so shown themselves to be intellectually the most able of the secondary school pupils. Hence the standards demanded should be such that a very high percentage of Higher School Certificate pupils should be successful. Further, the percentage should be approximately constant from year to year, and between subject and subject.

#### *Further Notes on Higher School Certificate Syllabuses*

##### CHEMISTRY

The standard expected by some examining boards appears to be much higher than that of others. Divergences between the syllabuses and the questions set are very marked ; also the standard of the question papers seems to vary widely from year to year in the case of certain boards who use a syllabus which gives too little detail.

The emphasis given to Physical, Organic, and Inorganic Chemistry varies. Most boards, but not all, make some Organic Chemistry compulsory. In some question-papers there is little sense of the fundamental importance of Physical Chemistry. One board has recently devoted special attention to the history of Chemistry without reducing a syllabus which teachers already consider more than full. Radioactivity, Atomic Structure, and other modern ideas are not included in some of the syllabuses.

The use of expressions such as "copper and its more important compounds" has led to differences of opinion and the list of elements to be studied varies greatly. The syllabuses in Organic Chemistry vary even more than those in the other branches of the subject. The omission of all reference to aromatic compounds in the new syllabus of one board is deplorable.

One or two boards specify a restricted list of commercial processes on which questions may be asked; this practice seems very helpful. The experiment of one board in reducing its theoretical papers to  $2\frac{1}{2}$  hours is being followed with interest by science masters.

In practical examinations some boards allow the use of textbooks, others do not. The production of laboratory note-books is asked by some and might be expected by all. There is sometimes an alternative to qualitative analysis questions, and teachers welcome the growing tendency to omit the phosphate separation and not to set two metals which are precipitated in the same analysis group. Preparations and simple gravimetric exercises are usually included in the syllabus but can seldom be set as they are usually too long for a three-hour paper.

## PHYSICS

The syllabuses in Physics do not appear to differ as much as those in Chemistry, but there are wide variations in the standard of questions from board to board and from year to year. Two of the boards issue unduly brief statements of the work expected. With some boards the questions stress too strongly the mathematical aspects of Physics and make the subject unduly difficult for those candidates who do not also take Mathematics. The less mathematical and more experimental papers of another board might well serve as a model to be imitated. The regulation that Applied Physics may be taken in those schools which are sufficiently well-equipped is to be commended.

Work expected in Mechanics and in Properties of Matter shows wide variation. One board has no Mechanics syllabus, another gives no details. Projectiles, centres of pressure, torsion, and the compound pendulum are usually excluded and one board omits any reference to surface tension.

Increasing attention is being given to the physical side of Optics though polarisation is seldom included.

Differences in the content of questions on Heat concern mainly the Laws of Radiation and of Thermodynamics.

In Electricity and Magnetism references to meters, dynamos, and alternating currents are appearing, with occasional questions on the thermionic valve and on the electron. Magnetic hysteresis is sometimes included and the quadrant electrometer is asked for, although schools seldom possess this instrument.

## BIOLOGY

The content of the syllabuses of the various boards is about the same but the arrangement of the syllabus by some boards seems ill-considered. There has been a welcome tendency to reduce the number of types which must be studied in detail. It is to be regretted that the boards seem disinclined to let teachers use the most convenient examples for illustration. This is particularly important in the section on physiology where, in nearly all cases, one is instructed to use the types traditionally used for teaching comparative anatomy. Unfortunately, research workers seldom use the same species, and the teaching of physiology is necessarily hampered. Much the same applies to parasitism, for which the almost universal example is the tapeworm, an animal which is a highly specialised form with no close free-living relatives. The nematodes, much more important and of much more interest, are seldom specifically mentioned.

Notable omissions from certain syllabuses are hormones, vitamins, and the physiology of the nervous system.

## BOTANY

The botany syllabuses of all the boards are very similar, and a successful attempt has been made to relate them to Botany as now taught. All the schedules include a good deal of Physiology, though one of them omits respiration and transpiration. Some study of Ecology is almost always required and most still ask in addition for the intensive study of a long list of families of flowering

plants. Two boards require no knowledge of evolution, a strange but presumably a deliberate omission. One board asks for the special study of one of a list of topics ; if this produces successful results, the idea might well be taken up by other boards and for other subjects.

### ZOOLOGY

The general content of the syllabuses is much the same though there are very great differences in the manner of statement. The same criticism must be made here as is made of the biology syllabuses, that to use a fixed list of types is not the best way to illustrate either Physiology or such general topics as Parasitism and Reproduction.

The fact that certain species are mentioned encourages the student to restrict himself to these. Several of the schedules are much too short in statement. One demands that a list of types should be used to illustrate " the fundamental laws of zoology," but leaves what these are to the discretion of the teacher and the examiner.

### GEOLOGY

Owing to different ways of setting out the syllabuses, comparison between the schedules of the boards who set papers in Geology is not easy. The questions seem, however, to suggest that there are not great differences except that one board lays much stress on Physical Geology. The practical work does show variations. One board specifies the microscopic examination of minerals and rocks, two do not specify any study of fossils, two mention field-work in the particular area near the candidate's school.

### GENERAL SCIENCE

Some boards have made the interesting experiment of introducing General Science syllabuses for the Higher School Certificate. These syllabuses do not seem to have been very popular.

### SUBSIDIARY (OR COMPLEMENTARY) SUBJECTS

We consider that the standard in a subsidiary subject, if it is to be examined, should be about midway between the School Certificate and the Higher Certificate. This is not so at present with certain boards where a subsidiary paper may be hardly different in standard from that of the School Certificate. The



type of paper set in a subsidiary subject may well differ considerably from that of a main subject, but care should be taken to maintain a reasonable standard.

### *Science for Non-Specialists*

As has already been stated, we feel most strongly that just as the science specialist should study "complementary" arts subjects, so the arts specialist should include some obligatory science in his or her course. In some schools such "complementary" science courses are already in operation.

It is obvious that the more formal courses of the specialist type are of little value for this purpose and there have been experiments with different types of courses to discover which is most suitable. Provided the course is related to the interests of both pupil and teacher and is such as to provide clear illustration of the scientific method of approach to problems, widely differing syllabuses may prove satisfactory. Many, however, will prefer a biological course, for Biology, the science of living things, contains material which is necessarily more closely concerned with man than is the content of any of the physical sciences : for this reason it is of peculiar value in the training of the educated man. We feel it important that those aspects of the subject which react most strongly on human affairs, and which we propose to call Social Biology, should be brought to the notice of *all* sixth form pupils. The actual content of the course must depend on the interests and abilities of the teacher, but the following syllabus contains many topics which teachers have used with success in sixth forms not specialising in science :—

Introductory : Meaning and scope of Biology, special difficulty of experiments in Biology, controls, examples of false deductions owing to the operation of unsuspected factors.

Classification : Variety, species, genus, scientific naming. The main divisions of the plant and animal kingdom. Meaning of some of the classical words employed in scientific work.

Characteristics of Living Matter : Metabolism, growth, reproduction.

Root, shoot, leaf.

The Energy Cycle : Photosynthesis and respiration.

Some simple organisms.

Physiology : Circulation, heart, lungs, skin, eye, ear. Food values. Vitamins, hormones, recent bio-chemical research.

Embryology : Comparative Embryology, Recapitulation Theory.

Evolution : Classes of evidence, difficulties, Dalton, Galton, Lamarck, Weissman. Present position.

Heredity : Mendelism, plant breeding. Biffin's wheats, etc. Chromosome theory, linked factors, colour blindness, haemophilia, environment, acquired characteristics.

Bacteriology : Semmelweiss, Lister, Koch, Pasteur, Ross. Filter-passers. Toxins and anti-toxins. Theory of disease. Immunity and inoculation. Common drugs and their action.

Plant and Animal Pests and Pest Control : Economic importance of phylloxera, rusts, rabbits, cotton-beetles. The balance of nature.

The Statistical Method in Biology and Science generally. Precautions necessary in collecting and interpreting statistics. Vital statistics.

*Another Syllabus for Sixth-Form Non-Science Specialists*

The following is a suggested syllabus of Science for sixth form non-science specialists reprinted from the *School Science Review*, No. 99, pp. 229-235, which also gives a bibliography.

## BEGINNINGS OF SCIENCE

The Greek contribution : actual discoveries : its more important aspect as indicating a new attitude to knowledge : Ionians, Socrates, Plato, Aristotle.

The inductive method, classification.

Greek medicine, astronomy, and cosmogony.

Greek society as a background to Greek discoveries.

Alexandrians, Archimedes, development of mathematics.

Degeneration of Greek spirit in the Roman world.

Continuance of Greek science by Islam throughout the Dark Ages.

Absence of scientific work in Europe in the Dark Ages.

Scholasticism and the suspension of scientific invention. The rationalism and theological emphasis of the Middle Ages.

The Renaissance. The emergence of the Scientific Method.

Leonardo. Bacon. Descartes.

## ASTRONOMY

The calendar ; navigation ; astrology.

Copernican revolution. Copernicus, Brahé, Kepler, Galileo, Newton.

A brief account of the solar system and its measurement. The possibility of life on other planets.

A brief outline of the methods of measuring distances, motions, temperatures, and compositions of the stars.

Galaxies, and conceptions of the universe.

## PHYSICS

### *Mechanics*

The development of the mechanical view of the universe. The work of Galileo and Newton.

The break with the mediæval outlook.

### *Heat*

The caloric theory. Joule and the kinetic theory of heat. The kinetic theory of matter.

The principles of conservation and degradation of energy.

### *Sound*

The nature of sound. Science and music.

### *Light*

The corpuscular and wave theories of light. Interference, diffraction, and polarisation. The photoelectric effect. The quantum theory.

### *Electricity*

The development of the study of electricity. Faraday and Maxwell.

The electromagnetic spectrum.

### *The Structure of Matter*

The discovery of the electron, X-rays, radio-activity.

The development of the conception of atomic structure.

## CHEMISTRY

The progress of chemistry as shown in the development of such subjects as the following :—

Iron and steel, with special reference to the social changes of the Industrial Revolution.

The occurrence and uses of other metals, and the importance of alloys. The geographical distribution of deposits and raw materials, and its economic implications.

Electrolysis and its applications.

Fuels.

Chemistry and agriculture.

The production and uses of an important chemical ; for instance, sulphuric acid.

Coal-gas industry, leading to aromatic compounds and their uses.

A simple introduction to organic chemistry, and the uses of organic compounds as dyes, and drugs ; plastics, and explosives.

### TECHNOLOGY

The technical discoveries in the Stone, Bronze, and Iron Ages.

Sources of power.

The development of the steam engine and the turbine.

Internal combustion engines.

The use of electricity for the transmission of power, and for communication.

Transport, especially its changes in the past two hundred years.

The social effects of technological changes, for example : the reduction of drudgery and want ; distribution of population ; the problems of leisure ; pollution of environment ; the influence of the machine on art and craftsmanship.

The relation between pure research and technical advance.

### BIOLOGY

A general revision of the characteristic properties of living matter with particular reference to Man.

A balanced diet. Dietary deficiencies in different parts of the world and especially in this country. Reasons for these.

The effects of the war on nutrition.

The ductless glands as an example of " automatism."

The problem of hereditary diabetes.

Nervous control. The brain.

Embryology, growth, and senescence.

Man's relations with other organisms. Diseases, including occupational diseases. Pasteur.

Immunisation and recent development of chemo-therapy.

Competition for food. Insect and rodent pests.

Agriculture ; soil exhaustion and erosion.

Evolution. The evidence of palæontology, comparative anatomy and physiology, embryology, geographical distribution, and biological races.

The evolution of man, his small place in time, and the peculiarities of his evolutionary history. The development of the theory of evolution.

Populations. Experimental population studies on animals, and the factors influencing fecundity, fertility, and death-rate. Population statistics.

Variation. The types of variation. The inheritance of acquired characters.

Heredity, Mendel's experiments and their practical applications, leading up to the chromosome theory.

Inheritance of sex. Sex-linked inheritance and its application to poultry.

Hereditary diseases and defects in man. More complex cases such as stature, eye-colour ; blood groups and their distribution. Races of man ; the impossibility of definition in terms of physical characters.

*The inheritance of mental characters. Difficulties of obtaining accurate evidence. The case of intelligence.*

The differential birth-rate. The importance of environment. Eugenics.

Modern Darwinism. Some of the philosophical implications of evolution, and possible application to religion and ethics. Extinction.

Competition within and between species.

Animal behaviour : tropisms, reflexes, instinctive and adaptive behaviour, learning, abstract thought.

Spearman's two-factor theory and its modifications.

Child psychology and practical successes in this field.

Intelligence tests. Mental deficiency.

Other schools of psychology. Psycho-analysis, its methods and conclusions. Remedial treatment.

Gestalt psychology.

Reliability of sense organs.

Suggestion and propaganda.

Free will and determinism.

#### THE UNIVERSITY SCHOLARSHIP EXAMINATION

Open Scholarships and Exhibitions offered by groups of colleges at Oxford and Cambridge are awarded on the results of special examinations : the papers are set by the respective groups of colleges. The examinations are competitive and the aim of the

examiners in setting the papers is to select the most promising candidates.

Representatives of the Science Masters' Association have met the science panel of the Cambridge groups and discussed the scope of these examinations. The examiners welcomed the co-operation of the teachers and agreed to set the questions on syllabuses approximating to those of the Higher School Certificate.

### THE PRE-MEDICAL EXAMINATION

The University Medical Departments and the Hospitals permit the taking of the first examination whilst at school. Exemption can be obtained by success in the Higher School Certificate with certain limitations. Certain medical schools demand separate passes in Zoology and Botany, whilst others will accept a pass in Biology.

## CHAPTER VII

### EXAMINATIONS

#### THEORY OF EXAMINATIONS

In any discussion on examinations it is important to distinguish between the tests set by teachers themselves and external examinations set by university authorities, local education authorities, or professional bodies. On the whole, teachers set tests mainly in order to discover gaps in the knowledge of individual pupils or weakness in the grasp of the subject matter by the class. They may also use them as a teaching device, e.g., in order to convince the class that it is necessary to repeat a given piece of work. It should be noted that no teacher would rely only on the results of written examinations for his diagnosis of the pupils' weaknesses or difficulties. He would amplify his investigation by asking questions, by conversation, by looking up past records of pupils, and so on. In addition, in such internal tests there is usually no question of "passing" or "failing," indeed, it has been shown experimentally that the introduction of such an idea into the internal examination is harmful. The object of the test is that it should act as a guide to the pupil. Nevertheless, even inside the school, the examination often has a wider aim than this : promotions may be decided largely from the scores obtained, or the examination may be used to decide which of the pupils shall specialise in given subjects. Here, then, the tests are being used largely to prophesy future achievement (prognostic tests). It is well to remember that a good diagnostic test is not necessarily an equally good prognostic test ; for different purposes different types may be needed.

External examinations are often either tests for the award of certificates of competence or else are intended to be prognostic tests.

(a) Clearly, in any highly organised community, certificates of competence have to be awarded to trained individuals largely on the results of examinations. It is essential, for example, that doctors, engineers, and teachers should be highly qualified,

and it is desirable that standards of competence should be kept high. Further, in such cases, the examinations used can be so arranged as to have high validity. One knows exactly what is aimed at and the tests can be arranged accordingly—it may be sufficient to see how the candidates tackle tasks of the kind they will meet in their future profession.

(b) In any community which attempts to grant ever wider opportunities to all on the grounds of ability rather than of privilege, an increasing number of scholarships, grants-in-aid, free places, etc., must be awarded on the results of examinations. Here the assurance of future proficiency forms the best ground for choosing the successful candidates. The tests chosen must therefore be such that they will be valid for such a purpose. As a rule achievement tests are employed, the argument being that if a student has learned well in the past he will continue to do so. In addition to these achievement tests an effort is made to see how the candidate tackles fresh work (problems), and an attempt may even be made to judge his personal character and his attitude to his work (interview). Some of the University Scholarship Examinations are of this kind.

It must be noted—

- (1) that in this case the concept of “passing the examination” involves no ambiguity. The number of grants available is known, and only that number of candidates can “pass”;
- (2) that the examining authorities usually know the kind of person for whom they are looking and have considerable past experience of the type likely to do well.

#### *School and Higher Certificate Examinations*

It is not easy to see the application of the above considerations to the examinations which concern nearly every child in a secondary school. The School Certificate Examination, for instance, is neither a certificate of professional competence nor a prognostic test. In consequence it is difficult to justify, in connection with this examination, either the idea of “passing” or “failing” it or the form in which it is set. In fact, any examination which sets out to see “whether a pupil has satisfactorily completed a course in a secondary school” mainly on the results of a short written examination and with little reference to the views of the teachers who best know the candidates,



obviously leaves much to be desired. Every subject taught in a school offers certain aims or objectives which it is hoped students will attain as a result of the instruction they receive. In Science, we hope that our pupils will acquire familiarity with certain material, ability to use certain facts and rules, the understanding of general principles or laws and the knowledge of how to apply them. In addition, we hope that they will acquire certain manual skills and will develop certain attitudes and sentiments. Evidently a satisfactory test in Science would be an instrument which would give valid and reliable evidence of the degree to which our pupils have reached the objectives of the teaching.

To obtain a test, or a series of tests, of this kind would therefore necessitate :—

- (1) Listing, in full detail, the objectives of a satisfactory school science course ;
- (2) Constructing examinations which would test satisfactorily the degree to which each of these objectives has been reached ;
- (3) Giving proper weight to each of the factors involved in order to reach our final estimate of the pupil's progress.

Evidently, to list these requirements is an acknowledgment of the difficulty of the task, and in addition it illustrates once more the artificial nature of the concept of " passing " and " failing."

In general, the purposes for which examinations are used are the following :—

- (1) Indicative—to assess progress and attainments ;
- (2) Diagnostic—to reveal the strength or weakness of candidates in applying their knowledge in new fields ;
- (3) Prognostic—to determine the capacities of candidates for further studies.

Often a single examination is used for more than one of these purposes, although it is by no means certain that it is equally suitable for all of them. Examinations of the type of the School Certificate primarily aim at being indicative, while scholarship examinations and examinations set by the various professional bodies are presumably intended to be prognostic tests.

Schools may be influenced by examinations indirectly. The syllabuses prescribed may, and almost certainly do, guide teachers in building up their own curricula : they may dictate to a large

extent the branches of the work to be studied and those to be omitted or to be given but cursory treatment. The examination results obtained may give some indication of the confidence which may be placed in the work and achievement of the schools. Unfortunately, results obtained in external examinations are sometimes used by headmasters, education committees, or boards of governors to compare the work of different schools or even of different masters within the same school. So many factors have to be considered that the use of the results of external examinations for this purpose is quite unfair and must be deplored. Much of the most valuable work done in the schools cannot be examined by the methods which are familiar to us ; this is especially true in Science. For similar reasons, there are serious objections to the publication of reports written by external examiners. Because of the incomplete information they give to outside authorities, such reports are very liable to mislead.

#### EXAMINATIONS AT THE PRESENT TIME

Existing examinations in Science may be classified as :—

- (1) The essay type ;
- (2) The " new " type of objective tests ;
- (3) Practical tests.

Most examinations to-day consist either of a number of questions asking for short essays to be written, or else combine such an essay examination with a practical examination. Some attempts have been made to utilise the new " objective " technique of testing, but this type of examination is by no means commonly employed as yet.

The familiar essay questions usually invite answers which involve :—

- (1) an exposition of theories ;
- (2) an explanation of processes ;
- (3) the solution of problems ;
- (4) descriptions of apparatus, instruments, etc. ;
- (5) historical surveys ;
- (6) estimates of practical and theoretical values, applications to life, etc.

Practical examinations usually test the ability of the students to

- (1) manipulate simple apparatus,
- (2) carry out simple measurements or qualitative operations ;

- (3) apply their knowledge of practical methods and procedures to new experiments ;
- (4) convey to others a clear statement of observed facts.

Oral examinations in Science have seldom been used. The difficulties of correlating the impressions obtained by different examiners, and the very unsatisfactory nature of such examinations, even in the hands of experienced people, are no doubt responsible for this.

Since examining presents so many difficulties, it is strange that little use is made of the judgments formed by those best qualified to make them—the teachers themselves. These have known their pupils personally, usually for years, and have watched their work and their progress. They should be able to grade their pupils in a more valid and reliable manner than a written examination set by outside examiners. The well-known fact that many teachers' estimates of probable success in the School Certificate examination correlate highly with the results of that examination is itself an illustration of this. The teachers know their pupils sufficiently well to be able to forecast fairly accurately their success in an examination which measures only part of their ability and achievement—mainly their verbal or linguistic ability and their power, under examination conditions, of writing down in essay form portions of the knowledge acquired. When in an individual case serious divergence is found between the examiners' report and the teacher's estimate, the matter should be very fully investigated. Evidently the teachers' estimates formed on a wider basis would be most valuable, and especially so if the teachers have kept systematic record of their pupils' progress, attitudes and character for some years.

In this country, the essay type of question is usually employed in external examinations, although in recent years experiments have been made with the "objective" type. It must be emphasised at the outset that there is no question of asking which of the two types "is the better." This is a vague question to which no answer can be given ; there is no quarrel between the two. The question is rather—"In a given situation, to test some specific point, which of the two types of examination is more suitable?" In exactly the same way a carpenter would never ask whether a chisel was better than a hammer, but only which tool was suited to a particular task.

In the essay-type examination, fairly general questions are asked

to which the candidate replies by writing short essays. He is given no adventitious aid of any kind, but is left entirely to his own resources. He has to choose the length of his answers and the kind of apparatus or process that he will describe. Clearly, such questions and answers will aid those bookish pupils with considerable linguistic facility and a ready pen. They can also be used as good tests of ingenuity ("Devise apparatus to show . . .") or as tests of the candidate's power to express coherently a long train of logical reasoning.

These and other powers of essay-type questions will ensure their retention in any future examination. Nevertheless, arguments can be urged against them. For example :—

(1) It is exceedingly difficult to mark the answers with any high degree of reliability, as the mark given to any question by different examiners will not be the same and the same examiner will vary his marking from day to day. To minimise this difficulty examining authorities now usually insist on the preparation of carefully worked out marking schemes. Even then it is very difficult to foresee all the variations presented by the candidates, or to evaluate their relative value.

(2) In an essay type of examination one cannot set very many questions, say, 10 or 12 for a three-hour examination. It is therefore difficult to obtain correct sampling, that is, to see that the whole syllabus is covered. The examination therefore becomes partly a matter of luck. For the examiner it is unsatisfactory since he cannot be sure that the candidates' answers really represent their knowledge of the whole syllabus. Furthermore, this failing encourages cramming.

(3) The essay-type examination tests mainly factual knowledge, verbally expressed. Evidently this demerit is not intrinsic to the form of the question. The concentration on factual knowledge has arisen from the well-meaning desire to set questions that can be marked objectively and not to penalise the average child by setting questions beyond his ingenuity.

The new-type tests have been devised to meet these objections, and they succeed in part. They consist of questions that can in all cases be answered either by writing one or two words (with no alternative correct possibilities), or by underlining, or drawing a line. There is therefore no possibility of variation in the marking, which is perfectly objective and, in the technical sense, reliable. Since these tests are somewhat unfamiliar to many teachers it

has been thought advisable to give examples of the main types that have been devised so far.\*

No matter what the intention, questions requiring essay-type answers put a high premium on the power of self-expression and on maturity. Yet all teachers are aware that pupils, especially in times of pressure or of stress, frequently fail to do themselves justice. Their immaturity shows itself in an inability to marshal their knowledge and their thoughts at the appropriate moment. Often they fail even to realise what is required of them, and it must be confessed that the wording of the questions sometimes proves of little assistance to them in deciding this matter. A little legitimate "prompting" often makes an enormous difference in both the quality and the quantity of the answers which an inexperienced examinee will give to questions. The new-type tests provide this prompting in addition to other features which render them valuable.

By means of objective tests it is possible to examine with reliability as well as validity those aspects of the School Certificate work which we have decided are the most important. Tests requiring answers of one or two words will serve to investigate to a large degree knowledge of facts. Questions which demand answers not exceeding a line or two of writing can provide tests of knowledge of generalisations. Other types of questions, such as supplying missing words, selecting appropriate pairs of terms, or deleting incorrect suggested alternatives can be used to a large extent to investigate applications of knowledge and reasoning from data. In other words, new-type tests are available for the conduct of part, at least, of the School Certificate Examination.

It must be recognised, however, that new-type questions alone cannot form a complete method of examination. Descriptions of practical procedure, application of theories, the working of problems, and the formulation of explanations, comparisons, and similar matters, must be provided for by essay-type questions. But the "prompting" referred to above is possible even here. Questions demanding short answers only should be asked (though a series of questions might quite well be the equivalent of "paragraph headings" of a composite essay).

By a combination of new-type and essay-type questions (of the short form) an examination could be conducted which would at one and the same time be an investigation of the work

\* See Appendix II, page 264.

done and provide means by which reliable results might be obtained.

Apart from internal school examinations, schools are directly concerned mainly with the School Certificate, the Higher School Certificate and various University Scholarship examinations. In addition, it is necessary to mention the Matriculation and Intermediate Examinations of the universities ; these affect some schools directly and the majority indirectly because of the possibility of obtaining exemptions as a result of success in the School Certificate Examinations.

### (1) *The School Certificate Examinations*

The School Certificate is intended as a leaving certificate to be taken by pupils of sixteen plus after a course lasting five years, but in practice some pupils, especially the brighter ones, take it at fifteen plus, after a four-years' course. Occasionally the examination is taken even at fourteen plus, after a very short course of two or three years, a practice to be deprecated most strongly.

The science subjects most frequently offered at present are Chemistry, Physics, Biology and General Science. Considerable numbers offer Botany or Physics with Chemistry ; a very small percentage offer Agricultural Science or Geology.

The chief features of the last few pre-war years were the great growth in the number of candidates in Biology from 1924 to 1936 and the rapid increase in the General Science candidates from 1936 to 1938. These increases were accompanied by a very large falling-off in the numbers offering Botany. From the statistics at present available it appears probable that these changes have been caused largely by

- (a) weaker candidates being entered for General Science instead of separate science subjects ;
- (b) many girls' schools taking Biology or General Science instead of Botany ;
- (c) the growth of biology teaching in boys' schools.

The report of the Secondary School Examinations Council Panel of Investigators on the School Certificate Examination, issued in 1932, dealt at length with the position of science subjects in the examinations set by the eight examining boards. The investigators reported that in their view the existing multiplicity

of subjects was contrary to the best interests of education, and recommended that only four science subjects should be permitted, General Science, Chemistry, Physics, and Biology. The applied sciences such as Domestic Science were condemned, either because they were concerned with technicalities and were therefore unsuited to the curriculum of secondary schools, or because they were more fittingly regarded as practical arts, the proper place of which was in Group IV of the examination. The investigators also commented unfavourably on the fact that candidates were able to pass in Group III in a single science subject such as Botany, or worse still, in a portion of a single subject such as Heat, Light, and Sound. They suggested, therefore, that virtually all science candidates be compelled to take a general elementary science paper which would include the elements of Chemistry, Physics, and Biology. Existing papers in the three separate subjects already mentioned were to be regarded as additional to the general science paper. They added that the choice of questions set in each subject should not be so large as to enable candidates to pass by studying only a portion of the subject.

Although this report did not meet with universal approval, a number of changes based upon it have already taken place, notably the disappearance of papers in which selected branches of Physics could be submitted. All examining boards now set a paper in General Science, but it is not likely to be made compulsory. Many teachers of Science will agree with the investigators that no single science subject can by itself provide a satisfactory training in Science, or give the pupils a sufficiently comprehensive idea of what Science means. Yet most science teachers are of opinion that it is not desirable that everything that is taught in school should be examined, or even examinable, and for this and other reasons feel themselves unable to support the recommendation as to compulsory general science papers. Some teachers still maintain that the study of any of the science subjects is sufficient for attaining the main objective of science teaching in schools, even if biological studies be omitted. But there is general agreement as to the desirability of the inclusion of both physical and biological science in the school, though not necessarily with a view to examinations.

The School Certificate examination in a science subject usually consists of one written paper of  $2\frac{1}{2}$  or 3 hours' duration, but for

subjects such as General Science two papers of from 2 to  $2\frac{1}{2}$  hours are usual. A practical examination is set by several examining boards, but is compulsory in only one or two instances. Theoretical papers usually consist of questions of the essay type. Nearly all the papers allow some choice of questions, but the possibilities vary widely. In Chemistry six questions out of eight or ten, or eight out of ten or twelve is the usual proportion; in Biology from five out of seven to six out of twelve is the range; in Physics the numbers vary from eight out of ten to ten out of twenty; in General Science the choice is rarely less than six out of ten.

While agreeing with the Panel of Investigators that it is unreasonable to allow too wide a choice, under the present conditions of external examinations, most teachers oppose its suggestion that alternative questions should be practically abolished.

The report of the Panel of Investigators also advocated the general setting of easy questions, with relatively high standards of marking. Most teachers of science agree with this recommendation, and regret that up to the present it appears to have had little effect on School Certificate examiners.

## (2) *The Higher School Certificate Examinations*

The Higher School Certificate is usually taken at the age of 17 plus or 18 plus after a two years' post-certificate course. Many scholarship candidates take the examination two or even three times in their attempts to obtain a state or other scholarship. Science subjects often form a separate group in the examination, the number to be taken varying from one examining board to another. By far the most commonly offered subjects are Chemistry, Physics, and Mathematics. A considerable number of candidates offer Geography, but the other possible papers—Botany, Biology, Zoology, Physics-with-Chemistry, and Geology—are taken by relatively few candidates. Most of the subjects named can be taken also at a lower ("subsidiary") level. The biological sciences appear to be increasing in popularity slowly, but not to the same extent as in the School Certificate examination.

In each main subject two papers of three hours each are usually set with, in some subjects, a three hours' practical examination. One examining board has made the experiment of reducing the length of some of its papers to  $2\frac{1}{2}$  hours. The papers are always of the essay type and usually require from five



to eight answers out of eight or ten questions set, the choice being sometimes restricted by a division of the question paper into sections. Subsidiary subjects usually involve a syllabus and a standard about mid-way between those of the School Certificate and those of the main subjects in the Higher School Certificate. In most cases subsidiary subjects are an optional addition, and the number of candidates taking them is very limited.

In the statistics which follow, figures for pre-war years have been selected since it is felt that statistics for 1939-45 have been affected by many outside factors irrelevant to our purpose here.

TABLE I.—NUMBERS OF CANDIDATES TAKING SCIENCE SUBJECTS IN THE SCHOOL CERTIFICATE EXAMINATION

Subject	1924	1936	1937	1938
Chemistry . . .	19962	29379	27762	25847
Physics . . .	11064	21598	21281	20377†
Biology . . .	32	13610	15303	16044
Botany . . .	18524	9835	8553	6871
Zoology . . .	22	45	33	Subject discontinued
Physics-with-Chemistry.	3200†	7169†	7465†	7625
Mechanics . . .	2165	1779	1670	1669
General Science . . .	1266	4368‡	4901‡	8752
Geology . . .	12	26	19	46
Agricultural Science . .	29	187	115	95
Electricity and Magnetism*	1744	2912	2724	2326
Heat, Light, and Sound*	2687	3094	2785	2533

\* These were separate subjects only at London and have been abolished since 1939.

† These figures include London "General Elementary Science."

‡ Includes figures for N.U.J.M.B. Paper I only.

¶ Includes both London "Physics" and "General Physics."

TABLE II.—NUMBERS OF CANDIDATES TAKING SCIENCE SUBJECTS AS PRINCIPAL SUBJECTS IN THE HIGHER SCHOOL CERTIFICATE EXAMINATION

Subject	1926	1936	1937	1938
Chemistry . . .	2255	3484	3691	3935
Physics . . .	2301	3533	3830	4038
Biology* . . .	56	543	627	802
Botany . . .	394	655	714	757
Zoology . . .	140	451	537	664
Physics-with-Chemistry	53	150	144	174
Geology . . .	Not given in official Board of Education returns	16	13	21
Agricultural Science . .		4	5	9
Applied Mechanics . .		96	85	92
Applied Physics . .		49	39	35

\* Includes London figures for both "General Biology," and "General Principles of Biology."

All examining boards require a practical examination in connection with experimental science subjects and usually demand a certain minimum percentage on this paper in order to secure a pass in the subject as a whole. There is one very important matter of divergence in the procedure adopted by the various boards. Most of them allow the practical test to be taken in the candidates' own schools, but one or two authorities hold their examinations in their own university laboratories, the candidates attending in groups. It has been urged that this method is not a good one, and that in spite of trouble occasioned to the teachers concerned, all practical examinations should take place in the schools of the candidates. This, it is felt, is undoubtedly correct and it is further suggested that there should be present an external examiner who should allot a definite proportion of marks for the practical test then and there, quite independent of what the candidate writes. In some subjects this proportion might be large. These marks might be allotted on the basis of the candidate's method of setting to work and experimental handiness and/or on the results of questioning while the practical work is in progress.\* At present there is no uniformity in regard to invigilation: sometimes an examiner is sent to each school, sometimes a non-science master invigilates, and often the science master himself does this work. It has been suggested that it might be possible to devise a system by which science masters in different schools visit one another's schools as invigilators, but this does not meet with universal approval.

There is also a lack of uniformity in the regulations for practical examinations in regard to the use of text-books or tables and the inspection of note-books and specimens. It is strongly recommended that candidates in Higher School Certificate practical chemistry examinations should be allowed to use text-books for both qualitative and quantitative analysis, that the use of mathematical tables should be permitted whenever necessary in any subject and that the practical note-books of all candidates should be taken into account in assessing the marks for all practical examinations.

The Higher Certificate examination is open to the criticism

\* Some examining boards in their practical Botany and Zoology examinations provide a questionnaire to be filled up by the invigilator. These are quite lengthy documents and ask for information concerning the candidate's work for the two years previous to the examination and during the examination itself. This seems to be a step in the right direction.

that it is made to serve several purposes at once. In particular, use is made of it for awarding state and local education authority scholarships. This leads to the introduction of questions harder than would normally appear in a Higher Certificate paper. It may also account for the publication of syllabuses of wider scope than they might otherwise be. The solution of this problem probably lies in the development of schemes similar to that already adopted by some examining boards, in which papers are set for scholarships additional to those by which candidates are able to qualify for the Higher Certificate. It is felt most strongly that the ordinary Higher Certificate papers should be framed with the sole object of fulfilling the function for which they are intended. If the technique of selecting suitable candidates for scholarship awards requires questions of a different character from, or questions dealing with a more advanced syllabus than, those suitable for Higher Certificate purposes, these questions should certainly appear in a specially constructed paper and not in the papers with which non-scholarship candidates are confronted.

The use made of the Higher Certificate examination for Intermediate exemption also has its effects, though in most cases these effects are probably less extensive than those produced by the entry of the competitive element.

### (3) *University Scholarship Examinations*

University Entrance Scholarships are awarded by all British universities, in the majority of cases on the results of examinations conducted by the universities themselves. In these examinations there is conspicuous lack of uniformity. In the number of subjects demanded, in the number of papers set in each subject, in the number of questions which must be attempted in the papers, in the syllabuses prescribed, and in the difficulty of the questions set, scholarship examinations differ widely not only from university to university, but even from college to college within the same university (this being markedly true at Oxford and Cambridge). In some examinations there is one paper per subject, in others two or more. In some there is a practical test, in others, none. The number of subjects taken may vary from one to four; the answers demanded are almost invariably of the essay type. The syllabuses range from little above matriculation standard to a standard even above that of a pass degree. There is no doubt

that the unduly high standard of the questions in some scholarship examinations, particularly those of the older universities, has had a bad influence on science teaching in the schools. In this connection the Committee desires most emphatically to endorse the statements made in the report of the General Science Committee of the Science Masters' Association.\*

#### (4) *Matriculation Examinations*

In such matters as subjects to be taken, and the characters of papers and questions, there are superficial resemblances between the School Certificate examinations and Matriculation examinations. The questions set in the latter, however, are liable to be more formal in type, and to require a higher standard of answering. Secondary school pupils at present usually obtain exemption from Matriculation Examinations by means of the School Certificate examinations. A recent development has been that pupils are now granted exemption by some universities, not only by passing in specified subjects at an adequate standard in the School Certificate, but also by obtaining both School and Higher School Certificates.

#### (5) *Intermediate Examinations*

Few schools are directly concerned with Intermediate examinations. The papers are not usually more difficult than those set in the Higher Certificate examinations. Often exemption from Intermediate examinations, in part or entirely, is obtainable by passing in appropriate subjects in the Higher Certificate examinations. Probably their only direct effect on work done is felt in schools taking the London examinations, where, although three subjects can qualify for the Higher Certificate, four subjects are required for exemption from the Intermediate examination. In the majority of these schools four subjects are studied and offered in the examination by practically the whole of their science pupils. It is likely, however, that in the near future London University will accept for Honours courses students reaching an approved standard in three main subjects of the Higher School Certificate examination.

#### (6) *First M.B. Examinations*

In order to shorten the long medical course it has become common practice in many schools for intending medical students

\* *The Teaching of General Science*, Part 2, p. 6. (John Murray.)

to take the first M.B. at school or to endeavour to secure exemption from it on the results of the Higher School Certificate examination. To the latter procedure most teachers can see no objection and in fact, they feel that a pass in Chemistry, Physics, and Biology as main subjects at the Higher School Certificate examination of any examining board should exempt the student from any first M.B. course. Many of the medical schools, however, prefer that courses leading to the first M.B. should be taken in a medical school, mainly because school instruction cannot give the necessary medical trend. It is felt that it should be possible to take the first M.B. at school and that the necessary medical trend should be given in the first year of the subsequent course at the medical school.

#### (7) *Local Examinations*

There are schools whose pupils are entered for the Junior and Senior Local examinations of certain universities. The teachers' associations have repeatedly expressed their view that pupils should not normally be presented for any external examination until they have completed a five-year course and have reached the age of 16 plus. It is felt that this view is thoroughly sound, and accordingly examinations which can be taken by pupils before they have reached the standard of the School Certificate are not discussed here.

#### VARIABILITY OF EXAMINATION STANDARDS

A study of the published results of the various School and Higher Certificate examinations reveals some curious anomalies and very disconcerting facts concerning the probability of success of the pupils who take the examinations. In subjects which are taken by relatively small numbers of candidates it is perhaps not surprising to find variations in the percentages of successful pupils from year to year. But it is difficult to believe that large variations are to be expected in the general calibre of candidates taking those papers which are offered by the majority of pupils taking the examinations. Still less is it possible to believe that the abilities of candidates in general will vary in a particular year as between those taking any given subject under different examining boards. Yet extraordinary variations are found in the percentages of successful candidates at the different examinations. The following are among conclusions

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arrived at from a survey of the published results over a period of three years (1936-38). As in Tables I and II, pre-war statistics have been chosen.

TABLE III.—PERCENTAGE OF PASSES WITH CREDIT IN THE SCHOOL CERTIFICATE SCIENCE SUBJECTS MOST COMMONLY TAKEN

Examining Board	Chemistry			Physics			Physics-with-Chemistry		
	1936	1937	1938	1936	1937	1938	1936	1937	1938
A . . . . .	55.6	64.8	61.9	58.0	61.7	62.4	56.6	50.4	56.1
B . . . . .	52.0	48.0	52.0	55.0	50.0	52.0	46.6	48.0	55.0
C . . . . .	59.9	54.8	58.1	57.3	57.2	57.2	45.3	42.2	51.1
D . . . . .	52.0	49.4	51.4	53.1	52.1	52.3	45.5	50.5	46.0
E . . . . .	49.5	49.4	49.0	49.5	47.2	50.7	46.7	52.2	49.1
F . . . . .	49.3	39.3	52.8	53.4	52.7	51.9	—	—	—
G . . . . .	60.3	54.5	56.0	55.6	55.7	57.5	48.1	52.3	52.2
H . . . . .	50.7	50.2	49.8	50.4	48.9	49.3	—	—	—

Examining Board	General Science			Biology			Botany		
	1936	1937	1938	1936	1937	1938	1936	1937	1938
A . . . . .	—	—	67.9*	38.5	43.9	45.3	77.7*	68.6*	65.0*
B . . . . .	40.0	43.0	49.0	43.0	45.0	50.0	48.0	45.0	47.0
C . . . . .	32.5*	44.7*	36.2*	54.4	55.1	59.4	57.9	68.1	63.8
D . . . . .	—	—	32.5	30.9	39.7	43.3	44.3	46.5	44.5
E . . . . .	55.1	46.8	54.9	45.6	47.3	47.5	44.2	43.3	44.1
F . . . . .	45.5	46.1	41.5	48.3	54.9	54.3	48.5	51.2	51.9
G . . . . .	41.6	43.7	45.8	42.2	44.2	52.1	44.6	43.0	51.0
H . . . . .	67.2	55.2	52.2	50.1	49.7	50.1	52.6	49.4	50.7

\* In these cases the particular Board had only a small number of candidates for the subject ; too few to give the percentage much significance.

TABLE IV.—PERCENTAGE OF PASSES IN THE HIGHER SCHOOL CERTIFICATE SCIENCE SUBJECTS MOST COMMONLY TAKEN

Examining Board	Chemistry			Physics			Biology		
	1936	1937	1938	1936	1937	1938	1936	1937	1938
A . . . . .	73.0	82.0	75.6	71.8	74.0	69.0	78.5*	85.7*	95.6*
B . . . . .	67.0	78.0	77.0	80.0	82.0	79.0	80.0*	76.9*	68.6*
C . . . . .	75.6	83.3	68.7	76.4	78.2	85.9	100*	100*	100*
D . . . . .	68.9	77.5	77.5	76.6	72.9	78.1	54.8	61.4	44.5
E . . . . .	74.7	75.1	84.5	76.1	75.2	84.4	76.4	77.5	85.7
F . . . . .	71.6	58.6	53.5	88.7	50.4	70.4	85.7*	100*	64.9*
G . . . . .	75.1	66.4	71.3	73.7	62.7	69.6	85.3	78.4	77.9
H . . . . .	63.0	64.9	65.9	64.6	66.4	65.8	58.7*	57.1*	79.5*

TABLE IV.—*continued*

Examining Board	Botany			Zoology		
	1936	1937	1938	1936	1937	1938
A . . .	91.3*	92.8*	85.0*	87.5*	89.4*	100*
B . . .	66.7*	82.4*	85.7*	68.8*	69.2*	70.8*
C . . .	100*	100*	94.7*	100*	100*	84.6*
D . . .	75.5	77.6	74.3	48.2	53.4	63.5
E . . .	74.7	77.1	83.3	72.9	73.1	86.0
F . . .	60.5*	63.6*	69.1*	68.4*	71.4*	72.2*
G . . .	96.4*	76.3*	69.1*	95.0*	88.4*	91.8*
H . . .	68.0	79.4	74.0	76.9	81.3	72.0

\* In these instances the number of candidates was too small to give the percentages much significance.

(1) In the School Certificate Examination of Examining Board H, the percentage of credits in Chemistry ranged from 49.8 to 50.7, which is quite reasonable. The corresponding variation in General Science is from 52.2 to 67.2.

(2) Examining Board D, one of the boards with the largest number of candidates, shows variations of from 30 per cent. to 43.3 per cent. in Biology, and a percentage of passes with credit of only 32.5 in the one General Science examination set.

(3) In one and the same year (1937), while only 39.3 per cent. of the candidates taking Chemistry under Examining Board F obtained "credits", the usual figure was about 50 per cent. and with Examining Board A as high as 64.8 per cent.

(4) Between 1936 and 1938 in the School Certificate Examination of Examining Board D, nearly 53 per cent. of the candidates taking Physics obtained "credits" while only 38 per cent. reached the same standard in Biology and about 45 per cent. in Botany.

(5) In one and the same Higher Certificate Examination of Examining Board D, the percentage of successful candidates in Chemistry was 77.7; in Biology it was 44.5, and in Zoology it was 36.5.

(6) Selecting two boards with very considerable numbers of candidates in Zoology, in 1936 the number of Higher School Certificate passes was 48.2 per cent. in one case (D), and 72.9 per cent. in the other (E).

(7) So marked are the tendencies in some of the statistics that candidates could undoubtedly be advised as to which board

gives them the best chance of obtaining a Higher School Certificate. For example, the candidate in Physical Sciences would do well to avoid Examining Boards F and H, where his prospects of success are either smaller or more problematical. Similarly, the biologist could not be blamed for avoiding Examining Board D, where his efforts do not seem to be sympathetically received at either School or Higher School standards.

Wide variations such as these may be explained by supposing either that the attainments of the candidates varied between wide limits, or that the examination tests varied. In view of the large numbers of candidates dealt with, and the known defects of the examinations themselves, the latter is certainly the more probable alternative, though it may not be so when the number of candidates is small.

It is particularly noticeable that the percentages obtained varied not only from one examining board to another (a variation which might indicate that the boards drew their candidates from schools of different average standards of efficiency), but also from year to year. The variations, too, are random, a point the significance of which will be clear to every statistician.

It is clear that some sort of standardisation is imperative. The present "element of luck" which appears to determine the percentage of candidates who shall be credited with success must be eliminated. It is true that the general magnitude of the variations is less than it was ten years earlier. Very definite improvement appears to have been made, but it cannot be disputed that there is need still for much more satisfactory control of the method of assessing success or failure. It ought not to be a problem very difficult of solution.

### *Machinery of Examinations*

#### THE SCHOOL CERTIFICATE EXAMINATION

In 1918 the School Certificate Examinations of the Oxford and Cambridge Joint Board, the Northern Joint Board, the Universities of Bristol and Durham, together with the General School Examination of London University and the Senior Local Examinations of the Oxford Delegacy and Cambridge Syndicate were recognised by the Board of Education and this



recognition was extended to the Senior Certificate of the Central Welsh Board in 1920.

The bodies responsible for these various examinations are differently constituted, but all include, in addition to university members, a certain number of co-opted persons who are acting teachers representing teachers' associations. Contact with teachers is also secured by annual conferences, by meetings held with representatives of associations concerned with the teaching of particular subjects (e.g., the Science Masters' Association), or through the activities of special committees.

These several Examining Bodies are independent of one another and each body, except in so far as its regulations are subject to the approval of the Secondary School Examinations Council, is solely responsible for the organisation and conduct of its own examination.

The Secondary School Examinations Council, in conjunction with the *Ministry of Education* has acted as a co-ordinating authority. Its present constitution (M. of E. Circular 113, 26/6/46) is :—

Chairman nominated by the Minister of Education ;  
Eight representatives of Local Education Authorities ;  
Eleven representatives of the teachers ;  
Six representatives of the Universities ;  
One representative of the Central Welsh Board ; and  
Five nominees of the Minister of Education.

The Council will in future act as an advisory body on matters of policy connected with examinations in all types of Secondary Schools and will continue to act as a co-ordinating authority.

Among the matters dealt with by this Council are (a) the recommendations of examining boards, (b) the maintenance of an adequate standard in the examinations, (c) the investigation of complaints with regard to examinations made by school authorities, and (d) promotion of conferences with examining bodies.

The Council are bound to consult the Ministry of Education before committing themselves on questions of principle or of policy which are controversial or specially important.

The examining boards are responsible for the appointment of Examiners, the setting of the papers, the making of awards

and the publication of results. There are three classes of examiners :—

- (1) Chief or Awarding Examiners, who usually set the papers and help in the marking ;
- (2) Revisers or Moderators, to whom draft papers are sent for criticism ;
- (3) Assistant Examiners, who mark the bulk of the scripts.

Two forms of certificates are issued. Certificate A is awarded to successful candidates who have been in continuous attendance for at least three years at schools recognised as efficient by the Ministry of Education, and have remained in school up to the age of 16 years. The Certificate is endorsed by the Ministry of Education with the statement that the Ministry has inspected the school, has recognised it as an efficient secondary school, and accepts the examination as reaching the approved standard and as being suitable to the school.

Certificate B is awarded to candidates who do not satisfy all the conditions previously stated. The endorsement is limited to a statement that the examination is an approved examination.

Usually there are two chief examiners for each of the main subjects. They are appointed annually and as a rule serve for three or four years. Chief examiners and moderators are either university teachers, teachers retired from service in secondary schools, or acting secondary school teachers.

The methods of the examining boards differ in their details, but the following procedure is typical of some, at least, of the more progressive boards :—

#### (1) *General Procedure*

In the first place, when the examiners (chief and assistant) are appointed, great care is taken in the selection and a reasonable balance is maintained as between school teachers and university teachers—actually in the case of one board over 70 per cent of the examiners are, or have been, engaged in teaching in secondary schools.

The examination papers are set by two chief examiners of experience, at least one of whom is engaged in school work. The questions are then submitted to a moderator, almost invariably a school teacher, for detailed criticism. The moderator has to decide whether the question paper covers the syllabus,

if all the questions are within the syllabus, whether the questions are clearly worded, and so on. Using the moderator's report, the draft paper is then criticised and amended where necessary by a committee which includes the chief examiners, assistant examiners with school experience, and a member of the board as chairman.

When the question paper is settled the chief examiners prepare a scheme of marking as an outline for their panel of examiners, but this scheme is altered in any way that may be found necessary at the examiners' meeting referred to below.

### (2) *Standardisation of Marking*

On the day of the examination ten scripts are selected by the Senior Chief Examiner from among those already arrived at the board's office. These ten are all specially selected as embodying difficulties of marking, or as being likely to prove borderline scripts. These scripts are photographed and copies made so that each examiner in the panel can be furnished with facsimiles of them.

Once the examination is over each examiner receives his scripts and after an interval of a day attends an examiners' meeting to discuss questions, answers, and marks, having in the meantime read and marked at least 25 scripts. By this means a large number of scripts are sampled and the examiners know fairly well the reactions of the candidates to each question. The discussion leads usually to some amendment of the scheme of marking. The meeting then proceeds to mark the ten photographed scripts. The first two or three are gone through verbally by the Chief Examiner with constant explanation and discussion. The remainder of the ten scripts are then marked independently by each of the examiners. When they have finished details of their marks are placed before the Chief Examiner. Any variations are noted and examiners are asked to justify any mark they have given which departs appreciably from the average. As far as time allows the whole of the ten scripts are thus discussed, so that all examiners can take away as standards ten difficult scripts marked and discussed by the whole panel.

### (3) *Examiners' Returns*

The examiners then mark their quota of scripts and send in with their last batch of marks a distribution sheet showing the

number of their scripts allotted each individual mark from 0 to 100. The Chief Examiners consider 25 marked scripts from each examiner's batch and these they re-value and discuss. If any alterations are necessary to bring the particular examiner's marking to the proper standard, these are made and, if necessary, the distribution sheet just referred to is consulted. Occasionally, the variations of an examiner are so extensive that all his scripts have to be remarked or certain whole questions re-valued. Finally, the whole result is examined and the various pass marks are fixed. This, it should be noted, is equivalent to scaling the marks.

#### (4) *Results*

Needless to say, all marking of questions in the answer books, transcriptions of marks, additions of marks, and making of alterations ordered by the Chief Examiners are checked very carefully at least twice. Since in the School Certificate the main object is to find whether each candidate has reached a certain standard ("pass" or "credit") the actual number of marks awarded is not of such great interest as the group into which the candidate is placed. Attention at the examiners' meeting is therefore focused largely on borderline scripts.

#### (5) *School Estimates and Compensation*

The schools submit an estimate of the performance of each candidate in each subject. This is used in considering and adjusting the marks of borderline candidates.\* The estimate also enables the board to check the results in the various subjects. Allowing for the fact that the schools cannot and do not claim their own estimates to be infallible, high degree of correlation has been found between the school estimates and the examination results in the various subjects.

Some examining boards issue a general report on the examination. These reports point out common errors and weaknesses revealed by the scripts.

If the machinery of all the examining boards was as carefully devised as that of certain of them, there would be few grounds for complaint. Unfortunately this is not the case, and the examination machinery of most boards could be much improved. The examiners, both chief and assistant, should be men with wide

\* In one year the use of school estimates and compensation were responsible for 8.5 per cent. of the certificates awarded to successful candidates by this Board.

experience of teaching in secondary schools, and still more, *all* examiners should be men with understanding of the psychology of children of School Certificate age. It is in this latter direction that so many university examiners (and not a few teacher examiners) fail. Until these difficulties are remedied we shall continue to find in some Examining Boards' General Reports the somewhat ridiculous complaints that "the standard of the candidates was too low," or that "many of the candidates were immature," and we shall continue to find that questions are set which are too difficult, too vague, or partially outside the syllabus.

Revision or moderation of the papers should only be undertaken by teachers who have recent experience of School Certificate work in their subject and who thus have first-hand knowledge of the standards that may be expected. Such moderators should be provided with model answers and a copy of the proposed scheme of marking. Questions may appear good, and yet the examiners' interpretation of them may be unsatisfactory.

#### THE IMPROVEMENT OF EXAMINATIONS

For many years it has been evident that there is a widespread feeling among science teachers that the time has come to make changes in the present system of examinations. Unfortunately, though many of the objections to the system are well understood, there is little agreement as to the methods by which they could be satisfactorily overcome.

It is sometimes suggested that the most suitable method by which criticisms of the existing state of things could be met would be by the complete elimination of external examinations for pupils who have no intention of proceeding to universities or to other places of further education, and this is the ultimate solution proposed by the Norwood Committee. Before approval can be given to this suggestion a consideration of the criticisms levelled against the existing system may be helpful.

Critics of the system claim that :—

(1) The examinations often dictate the teaching and the syllabuses, instead of following them. The more original and enterprising teachers are deprived of freedom and initiative, and encouragement is given to teaching methods which are devoid of vision and are directed primarily to obtaining at all costs examination successes.

(2) The papers which are set at present are well adapted to the academic type of pupil, but they fail to interest or to stimulate those who do not intend to take up university or similar work. The interests and well-being of such pupils are sacrificed to those of the small minority who will proceed to courses of further instruction in the subjects concerned.

(3) The perpetual prospect of external examinations produces throughout the schools, both in scholars and in teachers, an "examination frame of mind." Subjects are taught and studied, not because they are worth teaching and studying for their own sake, but in order that their teaching and their study will result in successful examination results. The will to learn is dulled, and, the examinations over, the work ceases to have interest. Judged by its permanent effect, rather than by its immediate success, the teaching has failed, for it has not encouraged the growth of interests and incentives intrinsic to the work itself.

(4) The examinations fail in the very purpose for which they are intended. They distinguish those who have "examination facility" and those who have successfully acquired what is known as "examination technique." They handicap pupils whose ability to express themselves well in writing or whose power of marshalling their knowledge in the manner required by the examiners is weak. They thus emphasise one aspect of ability, giving it undue importance. Furthermore, they completely fail to assess personal qualities. They therefore fail to indicate with any reliability the immediate or the potential value of the candidates in any way other than their ability to write well or badly on the subjects examined.

(5) The examinations are far from being infallible. Variations from year to year in the proportions of successful candidates and the occasional divergences between teachers' and examiners' estimates make it clear that the system in its present form requires considerable improvement.

(6) The publication of the results of external examinations is used to drive teachers and pupils unduly, and frequently to drive them along the wrong lines. Often the annual list of successes is regarded as a legitimate form of advertisement for the school. The success of teachers is judged by the percentage of their examination successes and lack of success may lead to insecurity of tenure or to dismissal. Even pupils whom the teachers know to be unworthy of success must at all costs be "pushed through"

the examination, all other objectives being discarded, or at least, relegated to a position of minor importance.

Perhaps the case against the present system is here overstated. It might be pointed out that :—

(1) The best teachers need not and do not completely sacrifice their initiative and freedom of action. Against restrictions which may be imposed upon freedom of action must be placed the undoubted incentive which is provided by the examinations—even though it be an extrinsic and temporary one.

(2) Whether the examination system is responsible or not, the standard of work and attainment has undoubtedly improved during the years in which the present system has been in operation.

(3) Whatever the effect of the examinations may be on pupils who do not proceed to the university, for those who do so the examinations undoubtedly provide a series of valuable “stepping stones” by which their progress may be judged.

(4) The examinations provide a certain standardisation of requirements from the schools, whose curricula and organisation are, in consequence, simplified.

The relative importance which must be attached to various arguments such as the above raises a problem of some difficulty. It seems that against the alleged restriction of syllabuses and methods attributed to the influence of the present examination system must be placed considerations of incentive and of simplification of school organisation. It is not certain whether all the points of criticism would be removed by the complete abolition of external examinations; other difficulties would certainly be introduced, concerned with the requirements of matriculation and intermediate qualifications for intending university and professional students. The I.A.A.M. has therefore not felt able to support such abolition.

Very considerable modifications of the present examinations in Science, with which alone we are concerned here, appear imperative. The most urgent requirements are to ensure that the teaching of Science does not suffer, but, on the other hand, derives benefit from the existence of examinations, and to devise methods by which confidence may be established that the examinations succeed in fulfilling the purposes for which they are intended.

With these considerations in mind the following proposals are

put forward for the reform of the question papers in Science of the School Certificate examination :—

- (1) That no single paper should exceed  $2\frac{1}{2}$  hours in length.
- (2) That the total length of papers for each science subject should be between three and four hours.
- (3) That new-type tests should in future form a part of all science papers.
- (4) Since there appears to be little evidence of the successful use of new-type tests at the School Certificate stage in this country, the proportion of time allotted to new-type tests during an experimental period should be smaller than that which might be contemplated later if the experiment proved successful.
- (5) In the experimental period suitable lengths of time would be :—  
 For General Science—1 hour new-type ; 2 hours essay type ;  
 For separate sciences, 1 hour new-type ;  $2\frac{1}{2}$  hours essay type.

At first the proportion of marks allotted to the new-type tests should be about 30 per cent. Ultimately this proportion should be higher and if “passing” or “failing” is to continue, the total marks obtainable on new-type tests should be at least equal to the pass mark of the examination. Credits and distinctions (or their equivalents) would be obtainable only upon reaching an adequate standard in both parts of the paper.

These proposals seem to offer a practical method of obtaining the oft-quoted objective—“easy questions with a high standard of marking.”

In the Higher Certificate examination, where knowledge of facts is of relatively smaller importance, the proportion of new-type to essay type questions should be varied. It is suggested that the Higher Certificate theoretical examinations should consist as now of two papers of  $2\frac{1}{2}$  or 3 hours, in each of which 30 or 45 minutes respectively should be devoted to answering new-type questions, and the remainder to essay type. A pass should be possible on reaching an adequate standard in new-type answers together with a suitable (lower) standard in the essay type as well as in a practical examination. Distinctions and exemptions should demand a satisfactory standard in all parts on the examination.



After a careful consideration of the many problems connected with practical examinations the following suggestions are put forward :—

(1) That practical examinations in science subjects at the School Certificate stage are undesirable.

(2) In the Higher School Certificate examination there should be a 3-hour practical test in each experimental science subject.

(3) That new-type practical tests have not yet been sufficiently developed for their use to be recommended.

(4) The practical test should be held in the candidate's own school, with an external examiner.

(5) That a definite (and in some subjects large) proportion of the marks should be given for what the candidate actually does, and not for what he writes. This emphasis on the experimental side is absolutely vital.

(6) Teachers in schools taking a practical examination should be given adequate notice (at least 14 days) of what materials and apparatus are liable to be required.

(7) In the absence of reliable laboratory assistance, masters should be allowed time within school hours to make the necessary preparations.

A cursory inspection of most of the question papers set at present shows that they are heavily biased on the side of academic questions. In some papers the importance of Science to the individual and to the community is entirely ignored. For years science teachers have been discussing the objects of teaching Science in schools, and have reached almost unanimous agreement on general principles. These are discussed elsewhere; they can perhaps be indicated by saying that the objective is less the production of prospective science specialists than of pupils who have a realisation of the importance of Science in their own life and in that of their fellows.

It is strongly felt, therefore, that reform in the subject matter of at least some of the questions is imperative. Applications of Science to everyday life must be regarded as an essential part of a satisfactory examination paper. Perhaps this is less necessary in the Higher Certificate than in the School Certificate, yet even in the Higher Certificate, Science as it concerns the citizen must not be ignored.

As regards the scope of the Higher Certificate examination, i.e., the content of the syllabuses as well as the interpretation of the

syllabuses by the examiners, a question of wide importance is raised. It is dealt with elsewhere in this book.\*

The disconcerting lack of uniformity in the proportions of successful candidates in various examinations and in various papers in the same examination † is a problem which must be confronted without delay. The solution of the problem apparently involves an attempt at standardising the human factor.

### *The Examination of Examinations*

The publication by Hartog and Rhodes of *An Examination of Examinations* (1935) and of *The Marks of Examiners* (1936) showed that even with experienced examiners there can be wide variations in the marks allotted to the same script by different examiners and by the same examiner when re-marking in certain subjects after an interval of over a year.

The authors point out that this is not the only variable factor but that there is likely to be variability both in the condition of the candidate and in the difficulty of the paper set.

They are of the opinion that "a more extended use might be made of examinations which yield identical results when applied by different examiners (e.g., new-type or other "objective" examinations), but that the traditional essay examination should be preserved, because it tests, though at present with considerable uncertainty, skills which cannot be tested by new-type tests.

Among the various subjects in which the research was carried out the only science paper was in Chemistry. In this, 250 scripts were borrowed from an examining board. They had been written by candidates for a School Certificate three-hour paper with a choice of six out of eight questions.

Two panels of examiners each with one chief and six assistant examiners were invited to mark thirty of the scripts, these being selected as well as distributed along the normal distribution graph of the particular examination. The examiners were from the lists of another of the examining boards. The scripts were reproduced photographically after all traces of the original marking had been removed. Each chief examiner was furnished with a copy of the paper and with twelve trial scripts from the remaining 220. He drew up, independently of the other panel, a detailed marking scheme and discussed it with his own panel.

\* See p. 167.

† See pp. 191-194.

Each assistant was then provided with trial scripts, two good, two bad, and two medium, which he marked and returned to his chief for criticism. Then the thirty reproduced test scripts were sent to each of the assistant examiners, who were allowed one week for the marking.

Nine scripts from each examiner went back to his chief, who gave instructions for the adjustment of the marks of his assistants, e.g., add 5 per cent. to marks of A and so on. The resultant marks from the 180 papers were then put in order by the office and the mark list sent to the chief examiner, who fixed his own standard for pass, credit, and distinction. The result showed an average range of some 10 per cent. between the marks of examiners for particular scripts. The greatest range was from 21 to 49 per cent. for one of the scripts.

The conclusion drawn by the authors is that these results "as a whole show the failure of the marking schemes to secure either uniformity of marking, or uniformity in the allotment of awards." Perhaps this desirable uniformity might more easily be obtained if examining boards paid closer attention to school reports and school marks.

It is certain that discrepancies in marking are much more serious than is generally assumed, and that there is something seriously wrong with the reliability of examination marking. Even after making all possible allowances, it is impossible to regard the position with equanimity.

In view of the wide variations of the marks it is surprising and consoling to find that when the candidates are classified into the usual School Certificate groups of credit, pass, and fail, there were 16 out of the 30 who were placed in the same class by *all* of the 12 examiners; 9 might have been awarded either credit or pass; five would have got either pass or fail, and only one script is shown as being awarded 1C, 5P, and 6F. Of the five who might have passed or failed the consensus of opinion in three cases was very definite, 10P, 2F; 1P, 11F; 1P, 11F. The other two were doubtful—8P, 4F and 5P, 7F. Perhaps, therefore, the revising examiners would have done justice to some of the doubtful cases.

Numerous other investigations of great interest are recorded, including an attempt by two independent groups of distinguished and experienced examiners to pick out by interview the "best candidate for a certain post." The results showed that for some

candidates fairly close agreement was reached within each group, but widely different results were evident when the two independent estimates were compared. It is suggested that "it was largely a matter of chance whether they struck a topic about which a candidate felt so strongly that he was able to display his individuality." This is, indeed, a most serious indictment of our present examination system.

It should be noted that in the chemistry paper the markers were not responsible for the setting of the questions, nor were they provided with a marking scheme made out by the original setter of the papers. There is also little reference to the merits or demerits of the questions set, so that it may be reasonable to suppose that where examining boards take great care to set questions for which detailed marking schemes have been thought out at the time the paper is made, some greater consistency of marking is obtained, especially after all borderline scripts have been revised by the chief examiner.

The very discrepant results of the interview mentioned above raise the question whether the variations in marks of individual examiners may be less than variations of examinees from day to day, or from paper to paper. If this is so, the results obtained from the written paper may still be measuring the candidates' performances as accurately as we can expect to do.

Suggestions for overcoming variability in results, such as those reported above, include :—

(i) The new-type questions and short essay type questions recommended on p. 183 will themselves help to a large extent to overcome variations due to the examiners. There cannot be differences of opinions regarding questions of fact : in short answers where personal opinions can enter, the divergence which may arise will probably not be as great as on longer answers.

(ii) The variability of the work of individual candidates can only be allowed for by referring to reports from their schools. Reports are even now asked for by the majority of examining bodies, but results of the examinations sometimes tempt teachers to wonder whether any use is made of them. Probably the reports are of the wrong type. If, instead of assessing the standard of the work of the candidates, the schools were asked to arrange names in an order of relative merit based upon knowledge of their school records, the reports would be valuable. It is suggested that the names of candidates in each subject might be arranged

in five classes. The difficulty of collating estimates from various schools is well-known. "Good" from a school of low efficiency is liable to have a very different meaning from "good" from a highly efficient school. The suggested estimate of pupils from each school in an order of merit leaves the onus of assessing the general standard of the school on the examiners. But it removes the risk of injustice to the individual and this, after all, is the matter of overwhelming importance.

The work of a candidate whose examination result, relative to other candidates from the same school, places him in a position very different from that estimated by his teachers could then become a matter for discussion between the examiners and the school, so that before a decision is published it could be accepted by both sides. In discussions of this kind it should always be remembered that a candidate in an examination is more likely to fail to do himself justice than to give an unduly high impression of his abilities.

(iii) The variation of passes, credits, and distinctions in the examination can be eliminated very simply by adopting the principle that in all papers taken by relatively large numbers of candidates in all Certificate examinations under all examining bodies the percentage of passes, credits, and distinctions should be constant within limits of, say, 2 per cent. The percentage should be independent of actual average marks awarded by the examiners. It should be easy from the statistics which are available to determine the appropriate percentages, though this may be more difficult where the number of candidates is small. As an example, it appears that the percentage of candidates in each subject who obtain credits in the School Certificate examination is about 55.

#### UNIVERSITY SCHOLARSHIP EXAMINATIONS

It is not easy to make recommendations concerning scholarship examinations. But it must be stressed that the marked absence of uniformity in the various University Scholarship examinations which has already been recorded leads to very serious difficulties in the schools, and particularly in the smaller schools. It is felt that the ill effects of the present scholarship system on the work of the schools are such that proposals must be put forward to secure that the examination shall be of a reasonable standard and

the requirements of the various awarding bodies reasonably standardised. It is therefore recommended that :—

- (1) At the earliest possible moment there should be a wide extension of the system of consultation between teachers' representatives and scholarship authorities.
- (2) The syllabus of the examination should be that of the Higher School Certificate examinations, though the questions set would probably need to be more difficult.
- (3) Candidates should be required to take three subjects, or two main subjects and a subsidiary.
- (4) In all experimental science subjects there should be a practical examination as well as the theoretical papers.
- (5) All schools should be required to supply full reports on their scholarship candidates and considerable weight should be given to these reports.

In addition, it is felt that a considerable increase in the proportion of science scholarships relative to classical scholarships, especially at the older universities, is long overdue ; while at the same universities the abolition of compulsory Latin (or Greek) in the Previous and Responsions examinations is regarded as urgently necessary for those entering the universities to study Science.

## CHAPTER VIII

### TEACHING AIDS \*

In this chapter it is proposed to deal with some of the many teaching aids used in the science room.

A fact or process is more readily learnt if it is presented through the medium of more than one sense. The blackboard—the first and most important of teaching aids—is used to present facts visually, together with the verbal statement. Appeal is made through eyes and ears simultaneously.

Teaching aids may be divided into two main categories :—

- I. Optical Aids.
- II. Aural Aids.

#### I. *Optical Aids*

The function of an optical aid should be

- (1) to augment the blackboard work ;
- (2) to show an illustration to the whole class at the same time ;
- (3) to produce an enlarged image of a small specimen for a united examination ;
- (4) to present a dynamic picture of a changing phenomenon ;
- (5) to bring the outside world into the classroom, e.g., through the medium of the film.

*Types of Apparatus.* The main types are :—

For still pictures   Lantern      Epidiascope  
                          Episcope  
                          Film-slide and film-strip projector  
                          Micro-projector

For moving pictures.—Film projector (silent, sound).

All these have their special uses in the science department.

*Conditions of Use.* An optical aid is of greater use if introduced into a lesson naturally and informally and in such a manner that

\* The section of this chapter dealing with optical aids has been written with the co-operation of the Education Committee of the Scientific Film Association, founded November 1943, under the Presidency of Arthur Elton.

the class does not regard it as a "stunt." Little adjustment of the instrument should be necessary during the lesson; indeed, it is recommended that an instrument in frequent use should be permanently fixed and always ready for use.

*Darkening of Rooms.* Most optical aids require completely or partially darkened rooms for their operation. Strong, well-fitted, and smoothly operated blinds are essential to enable rooms to be darkened rapidly without disturbing any member of the class.

Ventilation is a special problem. Wherever possible, it should be solved in consultation with the school architect.

### *Screens*

Types of screen available include :—

(1) *Matt White Surface.* This type is non-directional; light falling upon it is scattered fairly uniformly through all angles. It is probably the best and cheapest screen for general use and is recommended in a square room where the class subtends a large angle at the screen. The matt white surface is the most suitable one for colour work.

(2) *Silvered Surface.* Silver screens are directional; a high proportion of the light falling normally upon them is reflected through a very small angle. The picture appears bright to observers looking almost normally to the screen, but weak to those looking more obliquely. Such screens are very efficient for long, narrow rooms. Silver screens are unsuitable for the projection of colour films.

(3) *Glass-beaded Surface.* These screens are directional; they are expensive but very efficient. Though easily damaged, they last indefinitely if used with care. A damaged surface is more noticeable on a glass-beaded than on a white screen. They are usually sold in protective enclosing boxes, fitted with mechanisms for rapid erection.

(4) *Translucent Surface.* This type may be used in a small room for rear projection. Rear projection is directional but the image from it is bright. Its advantage is that the "throw" (distance from projector to screen) can, with a suitable lens, be made small. The projection apparatus can be mounted front of the class, enabling the teacher to maintain his normal position throughout. The screen, of ground glass or some translucent substitute, is placed between the projection apparatus and the class; slides or films must be reversed in the machine to obtain



a correctly disposed image from the other side. Translucent screens can be used for colour work.

Certain projection instruments give a sufficiently bright image to allow their use in a fairly light room, where the screen is shaded from direct sunlight. This is an advantage of rear-projection ; here, the image suffers mainly by light falling upon it from behind. For classroom use, a large image is not necessary. Since the brightness of the image is inversely proportional to the area of the screen, a small bright image is better than a large faint one.

### *General Principles of Projection*

In most instruments used for projection of an image of a transparent slide or film, similar optical systems are employed. The source of light is a special high-wattage projection lamp. (Arcs are now obsolete for any but the largest instruments.) Adequate cooling is provided and is very necessary. The light flux from the lamp is collected and converged by a condensing lens before passing through the slide. An image of the slide is focused upon the screen by the projection lens. The focusing depends only upon the position of this lens and is independent of the condenser. The function of the latter is to pass as much of the light flux from the lamp as possible through the slide and projection lens. The condensing lens usually consists of two positive lenses mounted together. These are arranged to minimise spherical aberration ; when removed for cleaning, they must always be replaced the same way round in the mounting, i.e., with both plane surfaces outside. The position of the source must be adjusted so that the image is uniformly illuminated. The light flux should be brought to a focus at the projection lens.

Most film projectors have pre-focus lamps, specially made for each type of instrument and automatically fitting into their correct position without further adjustment.

### *The Lantern or Diascope*

The lantern is well known and only its advantages and disadvantages need be tabulated.

(a) *Advantages.* It is simple in construction and easy to adjust and operate. It has few moving parts which may go wrong. With a high-wattage modern projection lamp a bright image is obtained. Where the screen can be shaded from direct sunlight, a good instrument gives an image bright enough for daylight viewing.

It can be used for showing to very large audiences.

(b) *Disadvantages.* Lantern slides are costly, heavy, bulky, and fragile. The standard slide is  $3\frac{1}{4}$  in.  $\times$   $3\frac{1}{4}$  in. The relatively high cost of buying considerable quantities of slides has kept down the number of slides purchased and prevented replacement of old ones depicting obsolete apparatus. The standard lantern is undoubtedly the best instrument for showing to large audiences, but for classroom work it is being replaced by the film strip projector.

### *Vertical Projection*

Many lanterns in science departments can be used with slight modification for vertical projection enabling experiments on liquids, etc., to be projected. Some schools now possess ripple tanks which have similar optical systems. The uses to which the apparatus may be put, other than projecting ripples (e.g., magnetic fields, stream lines), should not be overlooked.

### *The Film Slide and Film Strip Projector*

This instrument is essentially a miniature lantern for classroom use; it is not recommended for use with large audiences. It is designed to take (a) single slides 2 in.  $\times$  2 in. (glass-bound with picture 24 mm.  $\times$  36 mm.); (b) four slides mounted together (glass-bound), and (c) a reel of any number of pictures on a strip of standard film.\* Its great advantage is the low cost of the material used. The power of the source can be increased but the heat thus developed affects the film. The solution to the heating problem may lie in the development of extra high pressure discharge lamps for projection purposes.

Though different sized pictures on the 35-mm. film have hitherto been used, the picture size has now been standardised at 24 mm.  $\times$  36 mm. in Britain.† The surplus 11 mm. in the width contains the sprocket holes and allows the winding mechanism to draw the film through the gate of the special attachment. This attachment should provide for easy threading of the film strip, which should not be scratched in passing through. Provision should also be made for a rotation of the winding attachment through  $90^\circ$ , so that the full width of the picture can be used in either a horizontal or a vertical position.

\* Standard is here used in the sense employed in cinematography. In cinematography, film 35 mm. wide is internationally recognised as the standard. All lesser widths are described as substandard.

† Modern film-strip projectors should have masks supplied with them to enable them to project film strips of the old size, 18 mm.  $\times$  24 mm.

The pre-war price of film strips was one penny per picture, or threepence per picture photographed from material supplied (the size used then was 18 mm.  $\times$  24 mm.).

Attachments for projecting film slides and film strips can be fitted to ordinary standard lanterns.

### *The Episcopa*

The episcopa is used to project an image of an opaque object, e.g., a book illustration. Only a small fraction of the light falling upon the object (that scattered by the object itself) reaches the screen. The screen image is therefore of low intensity and to improve it, high wattage lamps are used and the room must be efficiently darkened. To prevent consequent overheating good ventilation is essential and in some models this is effected by motor-driven fans. *It is always advisable in testing an instrument before purchase, to keep it running a considerable time to determine the adequacy of the ventilation system.*

The many good models available are expensive, because of the large aperture projection lens required. The instruments are heavy and cumbersome and not convenient for moving from room to room unless mounted on trolleys.

In most models the picture is placed upon a platform at the bottom of the instrument, which can be lowered by a lever. This platform should be capable of receiving bulky objects.

A small episcopa is easy to construct if a suitable lens can be obtained.

### *The Epidiascopa*

This is a combined epi- and dia-scope. The change from one type of projection to the other is effected by the simple movement of a lever.

### *The Micro-Projector*

This instrument, which is little used outside the biological lecture room, is simply a projection microscope. It is invaluable for showing microscopic slides and specimens to a class. A double nosepiece is a useful accessory in these projectors. Many good models are available.

*Those who are interested in the construction of the above devices in school will find much useful advice in the relevant pamphlets mentioned in the bibliography.*

### THE FILM PROJECTOR

The number of film projectors in use in schools is likely to increase considerably in the next few years. Since comparatively few science masters will have had experience in their operation, the following notes and recommendations concerning technical design are given. They refer to 16-mm. sound machines,\* but appropriate sections apply equally well to silent machines. *Sound films must never be projected on silent machines.*

Ideally the minimum provision for the average secondary school would consist of one large 16-mm. sound projector for the school and one or more smaller machines for subject use in classrooms.

*Power Supply.* All projectors should be power-driven. Most British models possess motors working off the full 230 volts A.C. or D.C. mains. Where the lamp requires 110 volts only, a series resistance or transformer is necessary. Certain American types of machine, designed to work off 110 volt A.C. or D.C., are satisfactory when supplied through a transformer from 230 volt A.C. mains. If these are operated off D.C. mains with one rheostat for lamp and motor, both these components must always be switched on together to give the correct load. Should the lamp fail during projection, almost the full 230 volt load is applied across the motor, causing damage to the cooling fan and the windings of the motor, if this is not switched off immediately or suitably fused.

*Light Source.* Projectors for use in school halls, or for rear projection, should be fitted with lamps of not less than 750 watts. Smaller models for use in well-darkened classrooms should be fitted with lamps of 500 watts. For the projection of colour films, even higher wattages are necessary to obtain a true rendering of colour values on the screen.

*Cooling System.* The cooling system should be capable of maintaining a stream of cold air both around the lamp and across the gate.

*Sound Head and Amplifiers.* A.C. amplifiers are more satisfactory than the universal type. For D.C. operation a small rotary converter is a wise investment.

The amplifier is better as a separate unit not incorporated

\* While other substandard sizes of film are available, 16 mm. non-flammable film is now the accepted gauge for educational, non-theatrical, and non-commercial purposes generally.

in the projector. For use in school halls its output should be not less than 15 watts.

Sockets for gramophone pick-up and microphone jack should be provided.

These should have volume and tone controls in addition to those for the film sound output.

All the controls should be arranged on one panel, illuminated by a hooded lamp, and their function should be clearly indicated.

There should be provision for coupling an extra loud-speaker.

*Exciter Lamp.* Models which use the projection lamp to excite the P.E. cell are apt to cause variations of quality and volume in the sound. The delicate adjustment of the optical system used for focusing the light on the sound slit may be disturbed by a slight movement of the filament in the projector lamp due to its high temperature. This throws the optical system out of alignment and the result is inferior reproduction. A special exciter lamp system should therefore be universally adopted.

*Cables.* All supply and speaker cables should be stoutly made of tough rubber and plugs should be so constructed that incorrect assembly is impossible. An earthing wire should be used.

*Lubrication.* Oiling points should be reduced to a minimum. They should be of the wick feed type and easily accessible.

*Gate and Threading of Film.* The gate should be of a simple design so that threading and cleaning are made easy. Adjustment of the gate tension should be possible. A pilot lamp should provide illumination for threading. A simple framing device is necessary.

All machines should permit the use of 1600 ft. spools.

Film libraries take a serious view of mutilation of film copies. Great care should therefore be used in handling films. The gate of the projector and the claw mechanism should be kept constantly free of dust and oil. The projector should always be stopped if there is loss of loop or any other indication of things having gone wrong.

*Speed.* The change-over from silent to sound speed (from 16 to 24 frames or pictures per second) should be effected by a simple switch (other variations in speed are contrived in the printing or in the production of the film). While silent films were formerly always shot at 16 f.p.s., this speed is becoming obsolete even for silent films. Films, silent or sound, are now usually taken at 24 f.p.s.

Still picture devices require the automatic insertion of cooling screens to prevent scorching of the film. A reverse switch is useful, but it is not essential.

*Accessories.* Rewinding should be done by hand on a solidly made re-winder, capable of holding 1,600 ft. spools. Rewinding at high speed on the projector is not good for machine or film.

Other essential accessories are :—

Splicer (film cannot be joined satisfactorily without this).

Spare projection and exciter lamps.

Spare valves and photoelectric cells.

A supply of spools (400 ft., 800 ft., and 1,600 ft.).

Extra lenses, if considerably different lengths of throw are required.

### TYPES AND METHODS OF USING MOTION PICTURES

It is important, in considering the uses to which films may be put in science teaching, to remember the special qualities of the medium. Its chief virtues are that it can portray moving phenomena with precision and clarity, that it can show realistically and in detail experiments not normally demonstrable in the science room, and that, through editing techniques, it can assemble and correlate illustrations of general principles widely separated in time and space. The film may also be used to show the relationship between scientific studies and their practical applications in the social and industrial life outside the classroom.

Slowed-down or stop-motion photography enables growths and tissue changes to be recorded, while fast-moving changes and high-speed mechanisms may be shown intelligibly by high-speed photography. Animated drawings provide the science teacher with perfectly drawn and moving diagrammatic illustrations. Modern animation techniques can be used to great effect for emphasis and exposition in the diagram film.

While the film has immense and exciting potentialities both for scientific research and teaching, it is undesirable that the replacement of a demonstration by a film should ever be contemplated. The film should be introduced naturally and without undue fuss into the lesson. The teacher should have a knowledge of the content of the film before he uses it with a class. This knowledge is best acquired by seeing and studying the film beforehand. Excellent teaching notes are provided with many science films.

The following notes on the main types of films are given as a general guide to their use.

(1) *Films as Illustrations*

A short film may be introduced into a lesson to illustrate a particular point in much the same way as a lantern slide, book illustration, or blackboard drawing might be used. The illustrative film should be employed naturally and incidentally and not be allowed to interrupt the normal tempo of the lesson. A specialised application of this type is the cycle film. Cycle films are either 50 ft. lengths or endless loops of silent film.\* These films enable cyclic actions to be seen over and over again and thus memorised, and by means of them, physical and mathematical rhythmic phenomena may be presented in a particularly vivid way.

(2) *Film Lessons*

A film may be used as the basis of a lesson. For this use, the teacher should have a detailed knowledge of the content of the film, and should plan the lesson around it. The exact procedure to be followed may vary with each film or with the teacher's individual methods. Certain general principles should, however, be observed, if the maximum value is to be derived from any film lesson. The teacher should spend a proportion of the lesson period in discussing the content of the film, in relating it to the work the class is doing, and in pointing out details worthy of special notice. The first viewing of the film may precede or follow the teacher's remarks. Carefully chosen oral and written questions should be used to test the pupil's grasp of the content of the film and his observation of detail. Many teachers conclude the lesson with a second showing of the film. This method, or some modification of it, ensures that the film is properly employed as an active teaching instrument.

The lesson film should be designed to present a single theme in bold outline, with apt but not confusing practical illustrations. The main object to be observed in each sequence should always be well to the centre of the photographic frame. The film should be simply but attractively produced so as to awaken youthful curiosity and wonder at an early stage.

\* Endless loops, which require special attachments on the machine for their projection, have the advantage that they may be shown repeatedly without rethreading.

*(3) Revision Films*

Film editing allows a wide range of material to be assembled in one short film. By this means the work of several lessons can be reviewed in a ten or twenty-minute film with economy and efficiency. As does the film lesson, the revision film lesson makes use of discussion and questions, but obvious differences in the proportions of time allotted to these will suggest themselves to the teacher's mind. The revision film should be completely free of extraneous matter or of theatrical trimmings, and should make good use of diagrams and changing viewpoints for emphasis and recapitulation.

*(4) Background Films*

A short film showing wide applications of a scientific principle may be used as a lesson illustration in the manner already described. In general, however, documentary and interest films providing a background to scientific studies are more appropriately used for mass demonstrations in the school hall or library.

Much of real, if indirect, value in science teaching can be achieved through the presentation of well-balanced and carefully chosen programmes of documentary films on industrial and social themes. An extensive range of such films, made under expert supervision by government departments and industrial bodies at home and abroad, is now available.

The relationship between specialist activities and the general pattern of living, the romance and excitement of scientific achievement, the beauty of natural phenomena revealed by photomicrographic and other techniques, may all be conveyed through these films. The cinema, which speaks an idiom readily understood by the youthful mind of to-day, has considerable dramatic and realistic possibilities. Reasonably employed, these can contribute considerably to the background and intellectual atmosphere of scientific work.

**SUPPLY AND CHOICE OF FILMS**

Certain films, both sound and silent, made officially or by industrial concerns, are available to approved borrowers free of charge. The distribution centre for officially made films is the Central Film Library, housed in the Imperial Institute. A number of documentary and applied science films, made under



industrial sponsorship, are available free of charge both through the Central Film Library and from the organisation concerned. Other films are available on hire from commercial libraries. Present hiring fees are, in most cases, 3s. 6d. per reel per day for silent films, and 7s. per reel per day for sound films. Copies of some of the films may be purchased outright.

There is a reasonable supply of films covering various aspects of the biological sciences, but other branches of science are not so well supplied with suitable films. Pure Science is not so well covered as is Applied Science. There is a great need for a series of films covering each of the major branches of Science.

Guidance as to the content and suitability of films may be obtained from the separate lists, and from the reviews in the *Monthly Film Bulletins*, published by the British Film Institute. These reviews are reprinted in the *School Science Review*. The publications of the Scottish Educational Films Association contain reviews of science-teaching films. The Scientific Film Association has recently published a selective and descriptive catalogue of available scientific films. *Documentary News Letter*, a periodical issued at two-monthly intervals, gives reviews of documentary and scientific films.

Reference to all these sources will be found in the bibliographical notes at the end of this report.

The relative merits of sound and silent films for various classroom purposes cannot be finally decided from the data at present available. While the majority of teachers undoubtedly prefer silent films for instructional purposes, it should be remembered that a very limited number only of sound projectors has so far been in use in English schools. Silent films are cheaper to make and simpler to project under normal schoolroom conditions. The teacher can stop the silent film at will and can provide his own comments on the film during projection. A good commentary to a film can, however, never be made impromptu. The sound film has the advantage of a perfectly timed and well-rehearsed commentary; it also possesses additional qualities of realism. The use of sound films extends considerably the range of material available. A reel (400 ft.) of 16-mm. silent films, shot at 16 frames per second, runs for approximately 16 minutes; an equal reel of 16-mm. sound film for approximately 11 minutes.

In general, it may be said that short illustrative films will

normally be silent, lesson films will be silent *or* sound, and programmes of documentary and applied science films for mass demonstrations will usually consist of sound films.

### *Museums*

The museums which schools are likely to use as aids in science teaching are of two main types: those which are maintained by the state or local authority (or in a few areas by universities and private bodies), and those controlled by the schools themselves. The two types will be used somewhat differently.

The deficiencies of the large collections in this country have been repeatedly stressed, and are discussed at length in the Carnegie Report. It may safely be said that many of the museums owned by the state or local authorities, or even by the universities themselves, are completely useless except in so far as a man with an expert knowledge both of their contents and of the subject with which they deal, can use them for illustration. A school can only make much use of a museum when the cases are definitely arranged for teaching rather than merely for recording or containing. Happily the number of rooms so arranged is increasing. There are cases in the National Collections in London, in the Natural History Museums at Manchester and Bristol, and in the Vertebrate Museum at Cambridge which can teach certain topics far better than the corresponding chapters in any text-book. Pupils should be encouraged to visit such displays independently, but it is essential that if classes are taken there, they should be small, and they should go during ordinary school hours.

The museums owned and maintained by the schools themselves are a totally different problem. Most of the older schools possess museums which too often become places for depositing old relics.

The foundations on which an ideal school museum should be based are three; a competent man in charge; an annual money grant for maintenance and purchase of material; and a room specifically for the purpose. Where there is some approach to these conditions, the museum can become an integral part of the life of the school. In a small way, teaching cases can be arranged similar to those referred to as existing in some of the large collections; much can be done with a small amount of material, aided by models, photographs, drawings, and wall charts. Labels

should be sufficiently full to need very little amplification by the teacher.

Most teachers agree that Geology, Botany, and Zoology as school subjects should be related as far as possible to the natural history and topography of the district. A school's museum can therefore very profitably aim at containing exhibits of local fauna, flora, and fossils. The actual collecting should, as far as possible, be the work of the pupils themselves, and care must be taken that mere collecting does not become an end in itself. Most flowering plants and many animals are much better shown living at appropriate seasons than exhibited as preserved specimens. The museum is a suitable place in which to house aquaria and vivaria provided it is near the biological laboratory.

Selected pupils may derive much good by working in the museum themselves. Only a few have the ability to do this, and it is only where the school collections are extensive that there is much opportunity. Specimens need continual re-arrangement as knowledge advances, and the work can often be well done by interested sixth-form pupils.

### *Charts and Illustrative Material*

Many science teachers are glad to take advantage of the generosity of manufacturers and illustrate their science course by making use of books, pamphlets, charts, illustrations, and samples which may be obtained from many of the larger industrial concerns. A great part of such material deals with chemical topics, and often is available free. In other cases, samples or special exhibits are available on loan.

With this material the connection of the school science course with the outside world is made evident, a sense of reality is introduced and the utilitarian value of the work done at school can be emphasised. From time to time lists of firms willing to supply such material have been published in the *School Science Review*.

## II. *Aural Aids*

### RADIO

The science broadcasts to schools in this country are mainly confined to Biology, Nature Study, and related topics. The theoretical study of Physics and Chemistry does not seem to lend itself to such teaching methods and so the radio is used only to give background talks in these subjects.

No doubt the experimental basis which teachers endeavour to adopt in school science courses tends to make radio lessons much less effective. At some future date, the development of television may, in some measure, compensate for the absence of the speaker. At the same time, there are fields in science teaching which could be illustrated by radio lessons. For example, some of the more descriptive work could well be broadcast if a suitable expert were available. Eminent research workers might be able to present simple ideas of their work, and the use of dramatic illustration could, at times, be adopted.

In general, however, radio is a much less useful aid to the teaching of the physical sciences than is the film. The latter gives both sight and sound and has the advantage that it can be repeated at will and utilised at the most convenient time.

### *Technique*

A great deal of what has been said with regard to the use of films in the classroom applies, with the necessary modifications, to the use of radio. There is, however, one great difference. Re-arrangement of the teaching periods is usually necessary for the radio lesson and this is often impossible.

The effective utilisation of school broadcasts is facilitated by the use of well-prepared teachers' handbooks suggesting methods of introducing the lessons and of following them up. Special notebooks may be of great value to the pupils and may help them to get the most out of the broadcast, but it will be unfortunate if the broadcasters are thereby encouraged to lean too much on visual material thus made available. It might lead them to attempt to do things which radio is not fitted to do and to turn their broadcasts into little more than lectures.

Most broadcasts require a preparation and all require a following-up. The preparation may merely aim at arousing an interest in the topic and at making sure that the pupils have the knowledge necessary to enable them to understand what is to be said. For instance, a teacher might do well to explain the meanings of certain difficult words that are almost sure to arise. It is also possible that he may wish to prepare the ground by a lesson or a series of lessons using visual aids or experiments.

During the broadcast the teacher has to keep silent, but he may occasionally write up difficult words on the blackboard as they occur.

Opinions differ as to whether children should be allowed to write notes during a broadcast.

The following-up of a radio lesson has three functions : (a) amplification of what has been said, (b) filling up gaps, (c) impressing what has been said. If the aim is amplification, experiments and demonstrations may be necessary. If, on the other hand, the aim is complementation, it may be sufficient merely to discuss the broadcast with the class and to make suggestions for further reading. If, however, the object is to drive home what has been learned, oral questioning, the writing of essays and blackboard summaries will all find a place.

### THE GRAMOPHONE

Although a product of the application of Science, the gramophone is not widely used as an aid to the teaching of Science. It can, of course, be introduced as an illustration of one means of recording sound and it is particularly useful as a means of introducing up-to-date experiments into lessons on sound- and wave-motions. There are available Sound Demonstration Records which illustrate the meanings of the various terms used in the study of sound, and there are several records of gliding and pure tones with which many demonstrations and accurate quantitative work can be carried out.

The International Educational Society (Central Educational Offices, 98, Clerkenwell Road, E.C.1.) have published a few lecture records by noted men of science on topics concerning mainly Astronomy and Biology.

## CHAPTER IX

### SCIENCE IN RURAL SCHOOLS

#### RURAL "Bias"

A rural "bias" for country schools is commonly supposed to be highly desirable, and the comparative failure of efforts to secure it is generally deplored : though perhaps "bias" is scarcely the right word, since it implies lack of balance and gives a wrong impression of the basic idea. As a general rule, the science curriculum of a country school should differ but little from that of a school in a large town, with no more rural bias than there is marine bias in a seaside town, naval bias in a dockyard town, or industrial or mining bias in areas devoted to these occupations. In rural schools only a small proportion of boys are farmers' sons, or intend to engage in agricultural pursuits—it may happen that such boys are not interested in farming at all, and look upon the secondary school as a means of escape.

#### THE RELATION OF SCIENCE TEACHING TO SCHOOL ENVIRONMENT

Nevertheless, effort should constantly be made to adapt the science teaching to the environment by bringing the work into intimate contact with the life of the district, whether rural or otherwise : this is inevitable wherever science teaching is anything more than a rigid preparation for examinations. The course loses much of its educational value if any branch applicable to agriculture is neglected, though it is undesirable that the entire syllabus should be restricted to rural occupations and interests—for the school cannot attempt to train farmers. Rural subjects may certainly be used as a means of education without being ends in themselves : a middle course must be steered between purely vocational instruction in crafts on the one hand and a series of academic lessons in the classroom on the other.

Certainly in the country this contact should be particularly easy. The science master has much of the material he needs close at hand in the local hedges and woods, ponds and ditches. There is every opportunity for lessons out of doors if he desires

them, though there are often so many distractions that time so spent may be wasted : for scientific excursions on half-holidays, provided these have a definite object in view : for a Natural History Club which meets frequently for the reading of short papers embodying members' own observations.

Attempts of this nature benefit all boys to some extent, as part of a liberal general education, but they should prove of special value to future farmers even if not expressly designed for this purpose. Boys properly trained would be much more willing and able to experiment with new methods, or to make trials on their own account ; they should also prove more competent to assess the results to the benefit of farming practice in general.

There is even some hope that the farmyard may eventually become as attractive a place as the office stool or the workshop bench now appear to be. Moreover, since it would appear that in future, candidates entering the veterinary profession will be required to have a greater experience of farming than in the past, this vocation is one which may very well be recommended to the secondary school boy keenly interested in Science.

#### GENERAL SCIENCE IN RURAL SCHOOLS

The various methods which have been tried to secure this rural bias differ mainly in the degree of completeness at which they aim. The least that can be done is to keep agriculture in view in the treatment of school science by introducing from time to time lessons and practical exercises showing the application of scientific principles : a weekly lesson on Rural Economy may perhaps be suggested, dealing with, e.g., the fertility of the soil, farming operations, stock raising, dairying, plant diseases, and pests. The teacher should draw freely upon outdoor illustrations ; the chemistry of nitrogen should include some account of proteins as well as of explosives : studies of capillarity and temperature should include soil applications : elementary mechanics may be illustrated by farm machinery, work on bacteria, etc., by the production of clean milk, animal physiology and hygiene by the feeding and care of livestock.

The most promising course, and that which will probably appeal to the great majority of teachers, is to devise a syllabus based on farm and garden practice and country life in general. In this, biological topics will figure more largely than others, but the physical and chemical—and perhaps geological—

groundwork is essential and nothing that is really worth while can be done without it. Broadly speaking, such a course would begin with a study of air, water, and soil : of plant and animal life : and the elements of mechanics, heat, and electricity. Such work may well lead on to studies of soil physics, the sources and use of manures, animal nutrition, and the principles of breeding, with visits to a neighbouring farm for observational purposes from time to time. The General Science will thus be interwoven with agricultural science, and the amount of the latter increased as time goes on.

The normal selection of subjects from the various contributory sciences will require drastic revision. Room must be found for the ruminants, for an extended study of milk, for the rotation of crops ; the chemistry must include starch and sugar. At the same time, a good many of the traditional topics can be dropped, more especially in Physics. It is suggested that the numerical work on expansion, magnetometry, and the laws of stoichiometry are such topics : the science master should concentrate on those physical and chemical processes which a country boy is likely to understand and appreciate.

### AGRICULTURAL SCIENCE IN SCHOOLS

In large schools, with their own farm, where sufficient land and stock are available, it is sometimes possible to organise a definite agricultural "stream" consisting of boys intending to take up rural pursuits. There is a place in a complete educational system for a few such schools, run as far as the science is concerned on the lines of agricultural colleges. For most secondary schools in country towns something that will suit the non-farmers is required ; in any case, these schools will usually be too small to run parallel forms throughout.

More frequently it is possible to organise a definite agricultural form, perhaps in the two years preceding School Certificate, the rural subjects occupying perhaps a quarter of the time. On the other hand, the specially "rural" work may be confined to lower forms, whose General Science course combined with practical work on experimental plots or in school gardens forms the groundwork for the School Certificate course in the upper school.

Much depends on the qualifications and interests of the staff, but it may well be doubted whether, on educational grounds,



such complete bias is desirable ; at any rate, it has had but few successes.

### THE INFLUENCE OF EXAMINATIONS ON RURAL SCIENCE

The attempts to design a satisfactory Rural Science course are seriously hampered by examination requirements. "Agricultural Science" and "Rural Science" are usually unsatisfactory from this point of view if only because they are not accepted as subjects for entrance to the professions or because matriculation exemption cannot be gained thereby. As a rule, "General Science" is preferable, though Chemistry-with-Physics and Biology are possibilities.

The General Science syllabus can usually be adapted to the purpose—even a four-year course allows of a certain amount of work outside its range. Thus, in the year before School Certificate soils may be studied in one term, bacteriology in another, and manures in the third ; or the summer term may include in the second year entomology, in the third grasses, and in the fourth plant nutrition.

### THE SCHOOL GARDEN

Many teachers find school gardens unsatisfactory—holidays interfere with sowing and many pupils get quite enough gardening at home—but a large garden is not necessary, use being made of a corner or border in the school grounds. Nevertheless, school gardens are well established, and often form the only direct contact with country life, even when they are little more than experimental and demonstration plots. As such, they are of little educational value if their use is confined to work on fertilisers. Many gardening problems lend themselves to experimental study. Such are early and late sowing, methods of preparing seed beds, transplanting at various distances apart, influence of hoeing upon a growing crop, soil temperature, moisture content under varying conditions, the methods of dealing with pests and diseases, and the Norfolk four-course rotation. Such work is perhaps more valuable than more or less complicated and often inconclusive manurial trials.

A school garden should not be required to show a profit, much less to provide vegetables for school dinners ; but if attractively laid out and well cared for it adds considerably to the amenities of the school. A wide range of vegetables should be cultivated,

but the school garden must not be a mere vegetable allotment : many kinds of flowers should be grown : an orchard containing both tree and bush fruit is most valuable, and there should be a lawn of fine grass. A vegetative propagation plot, supplying suckers, corins, bulbs, rhizomes, etc., for biology lessons, and two or three dozen maiden trees for pruning experiments, together with a supply of East Malling classified stocks for budding and grafting may well be added to the usual experimental plots.

Boys should be taught the correct use of tools and appliances, if they do not know it already : but it is not desirable that they should do much heavy manual work such as digging. For this some paid help should be available when the garden is a large one.

### THE SCHOOL FARM

Livestock is, for school purposes, limited to bees, poultry, and rabbits, if it is to be the property of the school and kept on the premises. The best plan for larger animals, such as calves, pigs, and goats is to encourage boys to form Young Farmers' Clubs, and to keep the animals at home. Hives may well be kept in an orchard and poultry in a small meadow, but a corner of the garden may serve if nothing better is available : rabbits need little space and equipment. In all cases, it is well to begin on a small scale, and wherever possible to have the housing and appliances made in the school workshop.

A serious difficulty arises during week-ends and holidays, since stock cannot be left untended : but this often proves less serious than is generally supposed. Boys living near are usually willing to take turns with the routine work, and sometimes the help of caretakers or groundsmen can be enlisted. If a livestock club exists there will be funds to pay for some help, and the sale of produce will also assist. An incidental advantage is that boys can be shown how keeping livestock may be made to pay, and so profitable sidelines for the future may be suggested.

Whatever expert help may be available in the district should be sedulously cultivated. Advice and information should be sought from friendly farmers and bee-keepers : much work can be done in collaboration with an agricultural or horticultural college : the Ministry of Agriculture experimental station at Rothamsted is always willing to help, and the regular visits of the county experts are indispensable. Moreover, most counties have a Naturalists' Society, which can be particularly helpful and stimulating.

In all such work as has been described, both on farms and in gardens, observation must be close and systematic, and records must be kept of work done, observations made, costs, etc. The diary form is of little use ; a loose-leaf system is suggested so that the information can be arranged according to subject.

Information and skill gained in such ways should, incidentally, prove of great use in the classroom. The anatomy of the bee, the life history of queen, worker, and drone, the community of the hive, the development of the hen's egg and the hatching and rearing of poultry, are examples of the valuable additional illustrations which become available when livestock is kept.

### THE TRAINING OF RURAL SCIENCE TEACHERS

The teacher should beware of attempting any such instruction as has been outlined without previous training, as well as practical experience and skill, and it may be added, real interest. Something towards this end might be done by studentships to the agricultural departments of universities ; and though it might be thought that such matters should not be included in a training course, Reading University (which has a well-equipped faculty of agriculture and horticulture), is definitely trying to cater for trainees who are interested in rural matters and who may possibly seek posts in rural schools. The course in Rural Science is made one of a number of optional subjects, of which each student has to choose one.

It should be emphasised that it is just this difficulty of combining teaching and organising ability with practical knowledge and appreciation of farm work which so seriously militates against the success of most attempts to introduce a scheme based on rural practice.

The teacher contemplating such work would do well to consult the leaflets and bulletins issued by the Ministry of Agriculture and also the Ministry of Education's pamphlet " Education and the Countryside," which contains a useful bibliography.

### POST-WAR AGRICULTURAL EDUCATION

This chapter would be incomplete without some mention of the Luxmoore Report on Post-War Agricultural Education. This report is mainly concerned with administration. Of this aspect of the report all that need be said is that those of us who teach in country grammar schools would prefer the administration to be

conducted as formerly through the Local Education Authorities and the Ministry of Education, as the minority report suggests, rather than through the elaborate machinery for a National Council proposed by the majority.

Many of the Luxmoore recommendations such as the raising of the school-leaving age and continued education are now embodied in the new Education Act. Of the actual work and syllabus content of the rural grammar school the report had little to say beyond deprecating the teaching of Science as so many separate subjects, encouraging "General Science" and an increased study of Biology, and discouraging the teaching of agricultural science and general agriculture.

Though the report has little new to say and has proposed some very cumbrous and unnecessary administrative machinery, it is of importance as showing an official interest in what has been too long a neglected part of our educational system. Moreover, the condemnation of vocational education "unless it is based on a sound foundation of general education," and the assertion that the town child ought, also, to have some knowledge of "the principles underlying the life and work of the countryside" are most welcome.

## CHAPTER X

### THE TRAINING OF SCIENCE TEACHERS

Many teachers and educators feel that the crux of the problem of educational reform lies in the training of the teachers who will be expected to put the new suggestions into operation. As a result, much consideration has been given in recent years to the problem of training. Besides the I.A.A.M., who some time ago requested the Board of Education to conduct an enquiry into the matter, the National Union of Teachers, the Training College Association, the Headmasters' Conference, and numerous other bodies have issued reports on the problem or set up committees to consider it. In March 1942, the Board of Education set up a committee under the chairmanship of Sir Arnold McNair to consider the supply, recruitment, and training of teachers and youth leaders, and this committee issued its report in 1944 (the so-called "McNair Report"). A consideration of the general recommendations of the various reports is obviously outside the scope of this book ; but it may be mentioned that one difficulty which is being found by all these investigators is that the courses offered by the universities appear to be becoming gradually less and less suitable for intending teachers. While on the one hand the schools are attempting to make the education they offer more realistic and more closely connected with the demands and problems of society, universities are making their courses increasingly formal and specialised. In addition, economic difficulties bar the road to effective reform. It is becoming increasingly evident that what is being attempted can only be achieved by increasing the length of the university course, and that the system of four-year grants necessary to tempt people to promise to enter a profession which, in comparison with others, is financially unremunerative, makes it difficult to select only those candidates who are eminently suited to teaching.

The training of the science teacher is only one part of the main problem ; but it has its special points of interest and contention, and on some of them we would offer our observations, admitting

frankly that they are tentative and designed to be considered by any body which enquires thoroughly into the whole question of the Training of Teachers.

### OUTSTANDING PROBLEMS IN TRAINING TEACHERS

Points which need resolving in the Training of Teachers in general include :—

- (1) The aims of the courses and, in particular, the aims of Method Courses ;
- (2) The value and proper place of " demonstration " lessons, either by a lecturer, a practising teacher, or a student in training ;
- (3) The relative values of teaching practice which is interspersed with theory, and teaching practice taken as a " solid term " ;
- (4) The proper qualifications for Professors, Lecturers, and Tutors in Educational Departments ;
- (5) The part to be played in training by practising teachers.

### SPECIAL CONSIDERATIONS IN THE TRAINING OF SCIENCE TEACHERS

In the training of science teachers, special points which arise include :—

- (1) The proper breadth of degree courses ; should they be " General " or " Specialist " Courses ?
- (2) The need of the science master for skill in " Laboratory Arts " ; no parallel for this exists in most other subjects.
- (3) The actual " teaching technique " of Science ; including as it does the art of devising and staging demonstrations and practical work, this involves covering much more ground than in other subjects.

### UNIVERSITY SCIENCE COURSES

Universities differ widely in the content of their Honours Degree courses in Science. We desire to emphasise that in our view :—

- (1) It is *essential* that the courses should be so arranged that every science teacher should at least be qualified to teach two science subjects\* up to School Certificate level, and ready to pick up in his stride within a year or two of beginning enough of a third science to teach a sound General Science course. We think

\* In this section the term " science subject " is not intended to include Mathematics.

it thoroughly undesirable that a science teacher should be a complete one-subject specialist.

(2) Many science masters would find it helpful if they were able to teach two science subjects to post-School Certificate pupils.

(3) No university course should encourage an undergraduate to study less than two sciences in his first year at a university ; and every facility should be given for the study of three. Where an "intermediate" examination of Honours standard exists (as at Oxford, with "Science Mods."), tutors should understand that a man who intends to teach should *certainly* take this examination rather than any specialised or easier alternative.

(4) In his training year, a student should teach and observe at least two science subjects, including, if at all possible, some physical and some biological science.

#### THE FUNCTION OF THE TRAINING DEPARTMENT

It must be clearly realised that the principal aim of any education department is not merely to train teachers. If the whole of the period available is to be taken up in teaching the student specific skills or methods that will help him to maintain order in the classroom, it is doubtful if it is worth while to set aside a special year. An apprenticeship system is quite effective for the transmission of trade-lore. The first aim of any education department must be to change people's attitude, so that they may approach the problems of their job in a professional manner. Considerations of this kind lead education departments to give courses on the theory of education, in which attempts are made to make the students understand that there are definite social reasons for setting up a particular educational system and testing its results by examinations ; to lead them to understand the reasons which underlie various educational systems.

In addition, it must be remembered that psychologists have discovered a good many facts about the development of the child which are not obvious at first sight. In rare cases, men who are particularly gifted in the close contacts they make at once with other individuals, and who have an intuitive understanding of the mind of the child, handle their pupils excellently without ever receiving advice from anyone. But there is no doubt that the average student, when well taught, derives considerable benefit from his study of the psychology of education.

A good deal of time is spent in education departments on "Methods" lectures. The aims here are two-fold: first, there is the immediate aim of suggesting to the beginner appropriate methods of approach; describing good techniques for handling material so that it may make its full contribution to the education of the pupils and give them helpful information of all kinds. Secondly, in many cases the "Methods" lecturer is faced with the task of doing his utmost to correct the unfortunate bias of some university courses. For instance, in many universities, students are turned out without any knowledge of laboratory technique (glass blowing, woodwork, etc.), are entirely ignorant of the history of the subject they have been trained in, and have no understanding of the methods of thinking typical of it. Increasingly, the university course concentrates on teaching particular skills and techniques applicable mainly to elementary research. The "Methods" lecturer endeavours to correct this bias by emphasising the social and historical bases of Science, and by stimulating thought on more fundamental problems concerning the implications of Science.

#### THE VALUE OF SCHOOL PRACTICE

If it is asserted that the particular aim of a course in education is to introduce the students to a serious study of education rather than to train them as teachers, it may well be asked why they are sent out on school practice at all. The reasons are obvious, however. First, no one would doubt that teaching under supervision enables the students to avoid the elementary mistakes which might otherwise harm them in their first posts. Secondly, it introduces into the education course a very desirable practical element—the teaching helps "to keep the feet on the ground."

With regard to the teaching practice which has been carried out in the schools, there are wide variations among the various training departments. Some arrange their practice in continuous periods; others send their pupils into schools for two days a week. It is impossible, at present, to say which of these two methods is more effective—opinions are divided and no one really knows. But whichever method is adopted, it must be remembered by teachers that a college staff cannot be fully responsible for supervision of the students' practice. In consequence, the supervision of teaching practice has to be left almost entirely to the school staff, and the college lecturer or tutor cannot do more than keep in



touch with his students and with the schools, and try to establish as much uniformity of practice as is desirable.

#### THE ATTITUDE OF THE SCHOOLS TO STUDENT TEACHERS

Schools vary very widely in the help they give the students. Sometimes their supervision and advice is extremely helpful, and in other cases it is almost useless. Such divergences are reflected in the progress made by the students. In the most helpful schools it is usual at the beginning of the period of teaching practice to give the student a great deal of actual teaching to do. This is a recognition that the observation of lessons is a very difficult business. Students who have no experience of teaching, when they are set to observe lessons, become to all intents and purposes ordinary pupils rather than observers. They take no note of the technique of the teacher, of his methods of obtaining discipline, of the way he distributes his questions throughout the period and remember only the material that has been dealt with. Observation of this sort is useless. It is much better to give a student actual teaching to do, and to let him observe when he has already mastered the elementary technique of teaching.

A number of the lessons given by the student are observed by the teacher. Some teachers take the opportunity given by the fact that a student is taking their form to mark homework or pupils' notes. In that case their presence in the classroom may, indeed, help to secure good order, but it is not helpful in teaching the student to improve his presentation or his class management. It is highly desirable that careful criticism of at least some of the student's lessons be given.

When criticising a student's lessons, it should be remembered that encouragement and praise of the good points are usually more effective than criticism and blame of the bad points. It is further essential to the learner that general and abstract criticism be avoided. No student learns much by merely being told "You'll have to be much more active," or "you must try to keep better discipline." What he finds helpful are specific criticisms of particular points, which may then be made the occasion of a wider generalisation, e.g., "When Jones asked that question, what you should have said and done is" . . . "At the end of the lesson you should have written upon the blackboard a scheme for . . ." and so on. If teachers are to do this in a helpful

way they will have to be themselves consciously aware of the principles of teaching, and they will have to know something about scientific method.

Most beginners are, quite naturally, unable to obtain the discipline which experienced teachers obtain without strain. The importance of this factor must not be exaggerated. Nearly every teacher learns how to obtain discipline after a few years' experience. Furthermore, the best disciplinarians are not always the best or the most stimulating teachers. Here again, specific criticism is better than general commendation, and it is well to bear in mind that well-prepared lessons, effectively delivered, often result in good discipline. When children are kept interested and busy, they seldom make nuisances of themselves.

#### THE ART OF DEMONSTRATION

Help in the art of demonstration should certainly be included in the training year. This might be done either (*a*) by sending science students for teaching practice only to well-equipped, well-staffed, and progressive schools, or (*b*) by having in Education Departments science lecture-rooms, equipped with suitable up-to-date demonstration apparatus, or by both. It is probable that the former is the easier to arrange. The lecturers in the Education Departments should be able to give instruction in how to demonstrate, but they will have to keep in close touch with modern ideas in the schools and they will probably find it a good thing to bring into their lecture rooms at intervals successful practising schoolmasters.

In giving instruction in the art of demonstration there is no need always to have a class of children present; occasionally it is a good thing for a lecturer, having gone over a lesson *without* a class to repeat it *with* a class, so that students may see how he contrives to attend to his material while attending to his class and causing them to attend to him and to the demonstration. Demonstration lessons tend, however, to be artificial, and the morals to be derived from them are narrowly circumscribed.

#### COURSES IN LABORATORY ARTS

We regard the provision of courses in "Laboratory Arts" as very important; at present very few Education Departments include them. Universities which include a good deal of manipulative work in their Honours Degree courses probably do not

need to make any special provision in the training year ; and there is a case for saying that this work should be done before graduation. Where it is not so done, it is the duty of the Education Department to make arrangements for a suitable course ; sometimes a local technical college may have better facilities, or be more able to cope with the number of students than the university science departments.

### RECOMMENDATIONS

If students are to obtain the maximum benefit from their school practice we recommend :—

(1) So far as the student's quality will allow, he should be treated in all respects as a master.

(2) Unless the school is warned that the student is not strong enough to do it, he should be given from the first at least one form or set for which he has full responsibility ; his supervisor should not attend his classes until about three weeks have elapsed.

(3) Meanwhile, the student should observe the teaching of as many teachers as possible. Teachers who take lessons in the presence of a student should be ready to discuss their lessons afterwards with him ; he should have been instructed in his department in the points to look for in teaching method ; he should not be (and rarely is) equipped with a cut-and-dried method of his own. A good education department sends out students not full of knowledge but full of questions, and teachers should be ready to do their best to answer them.

(4) However poor the calibre of the student, he must very soon try his hand at teaching. It is very difficult for him to observe fruitfully until he has tried and found the difficulties.

(5) Once a week, the supervisor should spend a " tutorial " hour with the student ; his past week's work should be reviewed, and his next week's work planned.

(6) Supervisors should remember to praise as well as blame when reviewing lessons, and *to be specific* ; general criticism is of small value. A few very good teachers may be poor supervisors, because they lead the " good, but unexamined " life ; they have never analysed their methods. In general, a teacher who takes the job seriously will find supervising a student valuable for himself even when the student is dull, and quite useful when the student is a man of ideas.

(7) When a teacher does not feel able to " leave " a particular

form for long with a student it is perhaps best to give him two or three consecutive periods with the form and allot him one topic to deal with.

(8) To give a good student a few periods of sixth-form work is encouraging to him, and often very valuable to the boys, since he may be in better touch with advanced work than the master, but a little is enough. He is likely to enjoy lecturing to the sixth, but not to learn much of the art of teaching in the process.

(9) Some headmasters or senior science masters in schools in university cities where there are several students attending the school, arrange periodical seminars where the students and a few masters discuss points of teaching technique. These discussions can be very valuable, and should be encouraged.

(10) In Science, a student can learn a great deal during practical work. He should also be initiated in the methods of keeping a stock-book, and of ordering and choosing new apparatus.

It will be seen that a great deal must be left to the schools by the education departments. This is inevitable. A teacher can be made only in the school.

#### THE STAFFING OF EDUCATION DEPARTMENTS

The training of science teachers is a comparatively new business, and there is not a great deal of experience to draw upon. It is not yet clearly known precisely what are the right qualifications for professors and lecturers in education departments. But there is one qualification which is regarded by all teachers as a *sine qua non*. In Science, as in other subjects, it is not unknown for the lecturers to be men or women with little teaching experience. We would emphasise that we regard adequate previous teaching experience as essential for any person attempting to train teachers. And by "adequate" we mean, as a general rule, at least ten years' experience in the type of school for which the trainee is being prepared. A university, in recruiting the staff of an education department, must consider other things beside finding a practical man; the lecturers should be scholars with broad educational interests and experience, and have the capacity for educational research and original thought; but we believe that schoolmasters as a whole will never have real confidence in the education departments until the bulk of their staff is composed of men who have taught for long enough in

schools to have found out their own mistakes. It may be that the emoluments of lectureships are not always such as to attract from their work in schools, well-established and capable science masters with opportunities for headships ; if this is so, it should be remedied. At least half the lectureships in education departments should be as well paid as a reasonably good headmastership or inspectorship. We repeat that we recognise that more than mere practical skill in teaching is to be looked for in a university lecturer in education ; but we are sure that the other qualities called for can be found amongst men with teaching experience.

It would be a very good thing if lecturers could occasionally take a term away from their post, in order to go back to school-mastering. If this were arranged by an interchange with a suitable schoolmaster, it would probably be enormously to the advantage of both. Experiments have been made on these lines, but not nearly as extensively as we would wish.

## CHAPTER XI

### FIRST AID IN THE LABORATORY

In an earlier part of the book \* reference has been made to the possibility of accidents in the laboratory. Although it is impossible so to conduct a laboratory that the risk of accidents is eliminated, it cannot be too strongly emphasised that it is the duty of a science master to exercise such care in organising and supervising experimental work that the risk is reduced to a minimum. Negligence in this matter may involve legal responsibility for damage, to mention but one consideration.† The main types of accident which may be expected occasionally in a laboratory are the following :--

- (1) Cuts and scratches ;
- (2) Burns and scalds ;
- (3) Eye injuries ;
- (4) Accidents arising from the inhalation of gases ;
- (5) Accidents arising from the introduction of poisonous or dangerous materials in the mouth ;
- (6) Electric shock.

The methods by which such accidents may be avoided will be clear to any master who has had experience of laboratory work. Care in the handling of glass tubing and glass vessels will guard against cuts. Burns and scalds will be avoided if burners and vessels containing hot liquids are invariably kept at the back of the bench and well away from the sink. By this same precaution eye injuries from the spitting of liquids and possibly the bursting of apparatus will be rendered improbable. Dangerous gases should be dealt with in the fume cupboard, or at least near a wide-open window ; the sucking up of dangerous liquids by the mouth should be strictly forbidden. When definite amounts of these liquids are required, either weigh out the required quantity or use a burette. Strict cleanliness of bench

\* P. 116 *et seq.*

† See p. 249 *et seq.*

and hands should be insisted upon, and it should be a rule that in the laboratory food should never be eaten.

In the event of an accident in the laboratory, immediate treatment is called for. Except in trivial cases of injury, the science master must bear in mind that the function of first aid treatment is not to supplant expert medical attention, but to minimise the seriousness of the damage and to ensure that no further damage can occur before treatment can be obtained.

Every science master should have an adequate knowledge of first aid. The St. John Ambulance Society and the British Red Cross Society organise courses in many districts and all teachers would be well advised to attend one of these courses. In a short chapter it is possible only to indicate general principles of first aid; it is recommended that in every laboratory there should be at least one of the books on First Aid named in the bibliography to this volume.\*

#### GENERAL OBSERVATIONS ON FIRST AID

Every accident must be regarded as serious until it is known certainly to be otherwise. Without exception, eye injuries must be considered as grave, and if complete relief is not obtained in a very short time medical treatment must be secured.

When an accident occurs, first aid treatment *must be applied at once*. At the same time steps must be taken, except in trivial cases, to summon medical help.

The procedure known to be adopted in some schools is strongly recommended, i.e., the establishment of a connection with a local hospital, so that cases can be taken there with the certainty of receiving emergency treatment at any time. In at least one school, all pupils contribute a penny each term towards the hospital funds—a private variation of larger schemes which are in existence.

It is advisable in the great majority of cases where medical help is needed to report the accident to the school authorities, so that the actual responsibility of summoning a doctor or ambulance is assumed by them instead of by the individual master who happens to be present.

It appears to be the practice in some schools to use laboratory reagents for first aid purposes. Such a practice must be strongly condemned. First aid chemicals must be pure beyond all doubt;

\* Bibliography, p. 275.

only reagents which are kept in a first aid cabinet and are used for no purpose other than for first aid should ever be used. A fully-equipped first aid cabinet should be kept therefore in every laboratory in a position where it can be reached without any delay whatever.

The following general rules may be formulated in regard to all cases of accident :---

- (1) The correct treatment must be given at the earliest possible moment ;
- (2) Unless it is *certain* that it is not required, medical aid should be obtained. In some cases it will be necessary to call a doctor or an ambulance ; in others it will be a wise precaution to send the patient, after treatment on the spot, either to a doctor or to hospital for examination.
- (3) In dealing with any wound, absolute cleanliness is essential. All materials brought into contact with a wound must be aseptic or antiseptic. The hands of the first aid worker should be washed, if possible, in water containing a suitable antiseptic.
- (4) It should be remembered that in any case of serious injury and sometimes in other cases, there is a danger of shock. Steps *must* be taken to guard against this.

The symptoms of shock are a weak pulse, pale appearance, and drowsy or insensible condition of the patient. There may be yawning or shivering. In severe cases it is possible for shock to lead to death by exhaustion. The patient in a serious accident—in the laboratory this will probably mean the victim of severe burning—should be kept warm by means of coats or blankets and by being made to lie near a fire. Hot-water bottles (which must be covered) may be applied to the extremities. Even after apparent recovery the patient should be made to rest for a considerable time before being accompanied home.

### *Treatment of Accidents*

#### (1) BURNS AND SCALDS

(a) *Burns by Dry Heat.* (i) The less serious burns—those in which the skin is not broken and no *large* blisters are produced—can be treated with a sterilised burn dressing, or can be covered



with tannic acid jelly or sulphonamide cream, and loosely bandaged.

(ii) Burns which are extensive will be temporarily relieved by the application of a pad soaked in a solution of one teaspoonful of bicarbonate of soda in 1 pint of water. Serious burns must never be treated with any form of grease or oil. Without exception, medical advice must be obtained, for there is a very great risk of sepsis. The victim of a serious burn must be treated to avoid shock.

(b) *Scalds* should be treated similarly to burns.

(c) *Burns by Corrosive Chemicals.* In case of contact of the skin with corrosive acids, alkalis, or with substances such as sodium, phosphorus, bromine, etc., the wisest laboratory first aid treatment is to flood the affected part with water *immediately*. The part may be placed beneath the tap (a child can be lifted and any part of his body may thus be treated) or water may be thrown on the part from a beaker, etc., or a cloth (handkerchief, duster, etc.) thoroughly soaked in water may be repeatedly applied. After thorough washing and the consequent removal of the corrosive the wound may be treated as an ordinary burn. Various specialised treatments are sometimes recommended, such as the application of sodium bicarbonate to acid burns, or of ammonia to bromine burns, but the science master who is without extensive experience of first aid is recommended not to attempt these. Solutions require time for their preparation or their procuring from the first aid box, while the tap is always at hand; the essence of emergency treatment is speed.

## (2) EYE ACCIDENTS

(a) *Solids in the Eye.* As a rule, grit and non-dangerous powders in the eye can be removed with the corner of a slightly moist handkerchief or with a camel hair brush, in the manner used for removing a fly from the eye. If there is irritation, relief will be given after removal of the solid by bathing the eye in warm water or dilute sodium bicarbonate solution in an eye-bath, and then putting a drop of olive oil on the eyeball. If necessary, a pad of gauze or cotton wool may be placed over the eye and covered again by a light bandage.

(b) *Glass in the Eye.* No attempt whatever should be made by the amateur to remove glass from the eye. A large pad of cotton-wool soaked in water should be placed over it and

bandaged so that there is no pressure whatever on the eye. The patient should be taken to hospital or to a doctor immediately.

(c) *Corrosives in the Eye.* The eye should be flooded with water in the way described for burns. The eye should then be treated as in (1) above. If the eye is still painful, in spite of the absence of visible damage, medical aid should be obtained. The teacher will be well advised in all but the most trivial eye accidents to obtain the advice or help of a doctor.

### (3) CUTS OR WOUNDS

The treatment of wounds may be summarised as :—

- (a) Arrest of hæmorrhage ;
- (b) Sterilisation of the wound ;
- (c) Protection from infection.

In cases of serious bleeding—from vein or artery—it is more important for the first aid worker to arrest the bleeding than to secure asepsis, for the patient will always be treated afterwards by a doctor.

(i) *Slight Bleeding.* The wound must be washed with clean water to remove dirt. Glass must be removed by sterilised forceps if possible. If this cannot be done, medical aid must be obtained. Cold water often stops slight bleeding. If it does not, the wound is washed with an antiseptic and then bound so that pressure is applied in such a way that the wound is firmly closed.

(ii) *Serious Bleeding.* Serious bleeding often cannot be stopped by pressure on the wound. Bleeding from a vein (distinguished from arterial bleeding by the fact that the blood flows in a continuous stream from the wound) is usually easily stopped by pressure on the vein a short distance below the wound. This pressure is usually best applied by the fingers. When bleeding is stopped, the wound must be washed with an antiseptic, and bandaged.

Bleeding from an artery—recognised by the bright red colour of the blood, and by the fact that the blood issues in spurts corresponding to the heart-beats—is stopped by pressure at special “pressure points” above the wound. These are points where it is possible to close the artery by pressure against the bone. The most likely form of arterial bleeding in the laboratory will be from the palm of the hand as a result of cutting by glass tubing. The pressure points then used are two in the wrist. It is not possible

to describe the method of stopping arterial bleeding in a book of this type. Every science teacher should make it his duty to obtain a demonstration from an expert in first aid. Pressure must never be applied to a wound if glass remains in it. If the glass cannot be removed, pressure must be applied below or above the wound as the case may be.

#### (4) GAS POISONING

It is very unlikely that in the laboratory a pupil will contract gas poisoning. Carbon monoxide poisoning is possible but very improbable in a properly conducted laboratory.

The inhalation of gases will possibly cause a feeling of sickness or of headache, or it may result in irritation of the mucous membrane of the mouth and throat. In any case the patient should be sent or taken into the open air until the effects have disappeared. Various methods are suggested for soothing an irritated mucous membrane. Condensed milk is said to be effective; probably the most satisfactory device is to suck glycerine and blackcurrant pastilles.

In the rare event of gas poisoning, the patient should be taken into the open air, and if unconsciousness ensues should be subjected to artificial respiration. This also cannot be simply described here. The teacher should arrange for a demonstration from a first aid or life-saving expert. Medical aid should, of course, be summoned.

#### (5) POISONS IN THE MOUTH

The material should be spat out at once and the mouth rinsed out repeatedly with water.

If a poison is swallowed, it is necessary to remove it at once. Non-corrosive poisoning is usually treated by the application of an emetic followed, after the poison has been vomited, by an emollient. Strong, common salt solution is likely to be the most readily available emetic. As an emollient, the patient may swallow olive oil.

If corrosives or irritants have been swallowed, the mucous membrane will be damaged, and an emetic must not be used. (An emetic should be given for carbolic acid, arsenic, and mercury poisoning.) Acids will be neutralised by the swallowing of lime water. Sodium bicarbonate is suitable for most acids but is useless if the poison is oxalic acid. Alkalies will be counteracted

by a solution of citric acid. An emollient may then be administered. For a number of poisons there are specific antidotes, such as colloidal ferric hydroxide for arsenic, but these will not be available in the laboratory and an account of them here would be valueless. It is very unlikely in the laboratory that a serious dose of poison will have been taken, and, pending the arrival of the doctor, olive oil or white of egg may be administered. Oil must not be given in cases of phosphorus poisoning.

Probably the wisest thing to do in a case of poisoning is to telephone to a hospital or doctor and to act immediately according to instructions received.

#### (6) ELECTRIC SHOCK

The current should be switched off and the sufferer removed from electrical contact by a person well insulated and wearing rubber gloves or by the use of a walking stick. If it is necessary, treatment should then be given for burns, shock, and fainting. It may be necessary to resort to artificial respiration.

#### (7) FAINTING

Fainting is likely to occur in the laboratory as elsewhere. It might occur to the witness of an accident to another pupil.

The patient will fall more or less suddenly and will remain motionless. The eyes will be half closed and the limbs limp. The pulse will be feeble. A person feeling faint should sit down and place his head downwards between his knees. If collapse has taken place, the patient should be placed on the ground or on a couch with his head as low as possible. Clothing round the neck and waist should be loosened and the face moistened with cold water. Smelling salts (or solid ammonium carbonate) may be held near the nostrils. After recovery the patient should be made to rest and should be kept warm. Sal volatile may be given.

#### (8) BANDAGING

It should not be necessary to point out that a dressing of lint or gauze is applied to a wound in order to protect it, and that a bandage is used to keep a dressing in position. A bandage or a piece of adhesive plaster should never be brought in direct contact with an injury.

Gauze has many advantages over lint as a dressing. If lint

is used, it is the smooth, not the fluffy side, which is placed in contact with the wound.

Bandages are of two main types—triangular, for rapid application to limbs and head, and roller, for more prolonged use and for fingers, etc. The correct application of the roller bandage is a matter which requires practice and experience except in very simple cases. Difficulties in this respect are now, however, eliminated. Elastoplast dressings, for small cuts, and gauze covered by elastoplast bandage, in other cases, make roller bandages unnecessary in the laboratory first aid box. Both the dressings and the bandage can be obtained in yard lengths, from which any length needed may be cut. The removal of the adhesive portion of the elastoplast is facilitated by the application of ether (methylated).

#### (9) FIRST AID OUTFIT

Forceps	Burn dressing (gauze)
Needles	Tannic acid jelly or sulphonamide cream.
Safety-pins	Vaseline
Scissors	Mustard
Camel-hair brush	Salt
Spoon	Sal Volatile
Eye-bath and dropper	Olive oil
Triangular bandages	Smelling salts
Elastoplast bandage	Tincture of iodine
Elastoplast dressing	Some proprietary antiseptic
Medicated gauze	1 per cent. acetic acid
Cottonwool	8 per cent. sodium bicarbonate solution
Fresh lime water	
Clinical thermometer	

#### (10) NOTE ON THE RECORDING OF ACCIDENTS

In the teacher's own interest, even if it is not demanded by the school authority, he should always make a record of accidents, however slight; and if there is the slightest possibility of a claim of any kind for damages he should obtain a signed account of the occurrence from the patient, countersigned by the laboratory assistant or other competent witness. In many schools a special form is used for the purpose. The usual headings are: Name, Date, Place, Occurrence, Purpose of Experiment, Damage, with, in some instances, a statement by the master in charge.

## (11) PRECAUTIONS AGAINST FIRE

Every well-conducted school has its own fire regulations with explicit arrangements as to what the occupants of every room are to do on the outbreak of fire. Usually directions are posted in each room. Obviously it is particularly important that there should be clearly understood fire instructions applicable to every science laboratory.

In addition, the following matters should receive attention :—

(a) The greatest care should be taken in the manipulation and storage of inflammable chemicals. Such substances, as well as concentrated acids, alkalis, and poisons, should be stored in a cool place inaccessible to the pupils. Dangerous chemicals should never be placed on shelves from which they are liable to be knocked down. Risk of fire or of injury would otherwise be introduced.

(b) Buckets of sand should be easily accessible.

(c) Suitable fire extinguishers should be at hand. They will need frequent overhaul to ensure their being in working order. Particular care should be taken to see that in the laboratory there are no extinguishers of the type which project a stream of water. Such extinguishers are worse than useless in the case of fires caused by sodium or liquids like petrol, ether, and carbon disulphide. They actually make the fire more intense. Carbon dioxide extinguishers are of limited use. Only those extinguishers containing an inert liquid such as methyl bromide or carbon tetrachloride, or those which project a " foam " should be fixed in the laboratory. Even if extinguishers are available, it is probably more satisfactory to use sand than anything else.

(d) The science staff must be familiar with the position and use of the fire appliances, methods of exit, etc.

(e) For schools which can afford it, an asbestos blanket is an excellent investment in case of clothing catching fire. It should be regarded almost as an essential in girls' or mixed schools. If an asbestos blanket is not available, a large, heavy blanket, preferably treated with a fire-proofing solution, should be included in the first aid equipment of the school.

(f) There should be a main gas stop-cock, the position of which should be known to the staff.

(g) There should be fire drill rehearsals.

## CHAPTER XII

### THE SCIENCE TEACHER AND THE LAW

#### THE LEGAL STATUS OF TEACHERS IN GENERAL

Every master should see that his appointment to the post he holds is embodied in an agreement or at least in a minute of the appointing body. If the school is one to which the provisions of the Teachers' Superannuation Acts apply, the agreement or the minute should state definitely that the master is appointed as a full-time teacher. If it does not, difficulties may arise later as to the amount of pension to be received. A Local Education Authority—but not a Board of Governors—may dismiss one of its officers, which term includes teachers “at pleasure”—in other words without notice and for no reason at all. The Local Government Act of 1933, however, gives authorities the power of making contracts which include among the terms the giving of a specified length of notice to terminate the agreement, and if the Authority avails itself of this power, the contract becomes binding on the Authority as well as on the other party to it. Masters directly employed by education authorities should, therefore, take special care to see that a definite length of notice is provided for in the terms of their appointment.

In itself, the law makes no distinction between a science master as such and any other assistant master in the same school, but, as his work calls for the use of dangerous chemicals and apparatus, the science master finds himself particularly interested in certain provisions of the law, e.g., those relating to accidents and their consequences.

Accidents can happen both to masters and pupils and it is necessary to examine their consequences under two headings.

#### ACCIDENTS TO SCIENCE TEACHERS

A teacher accepts the ordinary risks of his calling. He cannot, therefore, claim from his employers damages for an accident which is not due to their negligence—unless he comes within the provisions of the Workmen's Compensation Acts referred to below.

Again, the legal doctrine of common employment operates to bar claims for accidents resulting from the negligence or lack of skill of a fellow employee unless the employer has wittingly engaged an incompetent person.

In addition to this duty to employ competent fellow teachers and laboratory assistants, an employer is bound to maintain the premises in a reasonably safe condition for his servants to work in, e.g., he must keep in good order and repair fume chambers, gas and electric supplies and appliances, etc. It is therefore wise for science masters to report to their employers, or their proper agents, any disrepair or other defect of the premises or apparatus they are called upon to use and to make a note of the date and time of the report. Otherwise, subsequent to an accident to a master, there may be suggestions of contributory negligence, or, at least, of a willingness to run the risk arising from the defect.

On the other hand, it is a master's duty to refrain from using apparatus which he knows to be defective until its replacement or repair by a competent workman.

Under the Workmen's Compensation Acts a master whose remuneration does not exceed £420 a year can claim compensation for an accident even when there is no negligence on his employer's part. The amount of compensation receivable depends on whether the incapacity resulting from the accident is total or partial, temporary or permanent. It cannot exceed half the employee's earnings nor 30s. a week (with an additional war allowance of 5s.), and 4s. for the first two children under 15 together with 3s. for each additional child.

The compensation is furthermore granted for loss of earnings and is therefore subject to reduction in proportion to any sick or other pay received.

The Acts also accord death benefits of amounts that vary with the circumstances.

The benefits accorded by these Acts are entirely independent of those created by the Teachers' Superannuation Acts, and a teacher's rights under the latter are unaffected by the receipt of workman's compensation.

Employers naturally insure themselves against a claim arising under the Workmen's Compensation Acts and a claim for damages alleged to be due to their negligence.

Some are prepared to deal with the results of an accident that does not give rise to either of these claims by means of an "ex



gratia " payment to the master concerned. Others, again, attempt by insurance to protect their masters against the consequences of such an accident ; but it is not clear they have sufficient insurable interest for this purpose, which they can best attain by paying the premiums on policies taken out in the names of the masters to be covered.

Finally, it is wise for a master who needs to feel fully protected against an accident of the class now under consideration to take out a policy on his own behalf with a good company.

#### ACCIDENTS TO LABORATORY STEWARDS

Assuming that a laboratory steward is (as he should be and usually is) the servant of the school authority and not of the master, his position is the same as that of a master, with the exception that the Workmen's Compensation Acts are more likely to cover him.

#### ACCIDENTS TO PUPILS

If an accident occurs to a pupil, his teacher is not liable for its results unless he has been negligent.

Negligence may be defined as the failure to take care when care is called for ; and the measure of the care expected of a science master is that of a reasonable man with expert knowledge of his subject.

The precautions he would take will vary with circumstances, e.g., the nature of the experiment, the size and age of the class, and its disposition in the room. He should ensure that his pupils have, and understand, clear, concise rules for the handling of chemicals and apparatus. A copy of the rules may be posted in the laboratory as a constant reminder.

Careful consideration should be given to the selection of experiments to be done by a class and explicit warnings given when these call for special care on the pupils' part.

Whilst it is desirable for there to be good first aid equipment in every laboratory, there should be no hesitation in sending for a doctor when there is the slightest chance of a need for skilled medical attention. Failure to do so would constitute negligence. A teacher calling a doctor should make it clear to him that he does so as the agent of the authority or the parent so that the doctor does not look to him for his fee.

If a teacher is called upon, whether as a result of a claim for

damages or for any other reason, to make a report upon an accident, he will be well advised to confine his remarks to the facts within his own knowledge and not incorporate his theories of the cause of the accident. Such theories might suggest to the claimant's advisers that the teacher failed to foresee and guard against a risk. Before submitting his report, he should also take advantage of any expert advice at his disposal, such as that of his professional association.

When a claim for damages results in legal proceedings, these may be taken either against the school authority (as the employer responsible for its servant's negligence), or against the teacher himself; but it is also possible for the authority, the headmaster, and the teacher all to be joined as defendants in an action. By the Law Reform (Married Women and Tortfeasors) Act, 1935, damages attributable to negligence can be apportioned between those responsible for it.

#### ACCIDENTS DURING OUT-OF-SCHOOL ACTIVITIES

Where a teacher is asked or expected to take charge of out-of-school activities such as meetings of a school scientific society, he should ensure that these activities are recognised as school functions by his employers. Otherwise, subsequent to an accident, he might find himself faced with a denial of responsibility on their part. Some local education authorities have already published lists of the out-of-school activities which they recognise as coming within the scope of a teacher's employment and for which they accept responsibility. Such lists as have been published are usually found to include all those meetings and excursions common in secondary schools. They are of value not because they deprive an injured pupil of his right, in proper circumstances, to compensation from a teacher, but because they guarantee the latter of the employer's support in protecting his professional reputation and amount to a moral, if not a legal indemnity against a claim for damages.

In some of the activities now under consideration there may be the additional possibility of negligence by third parties, but this is not likely to increase a teacher's liability. In this connection, teachers in charge of parties visiting works, etc., should be careful about agreeing to guarantee the management against claims arising from the visit. Such a guarantee, if given at all, is more properly signed by the parents of the pupils concerned.

In return for undertaking many of these extra-school activities, a teacher may reasonably ask the parents for an indemnity against any claim made on a pupil's behalf and in respect of reasonable expenditure incurred for his or her benefit, e.g., in the case of illness, and so on. Such an indemnity is not an absolute protection, for its value naturally depends upon the financial resources of the person signing it. As to the form an indemnity should take, teachers should consult their professional associations.

#### INSURANCE AGAINST CLAIMS FOR DAMAGES

Some associations, including the I.A.A.M., offer their members such a large measure of legal and financial assistance to meet claims for damages that membership is in itself a form of insurance and members should acquaint themselves with the nature of the cover afforded them.

Members seeking additional protection and teachers who are not members of such associations, will naturally wish to consider the advantages of a policy of insurance with a good company.

There is an impression that such a policy is of no value because it will not operate in the event of a claim based on negligence. As pointed out above, negligence is the basis of every well-founded claim ; and this is recognised in a policy of insurance. It is true, however, that a policy usually contains a safeguarding clause that would make the policy inoperative in the event of a flagrant attempt to abuse its protection by a deliberate neglect, such, for example, as a deliberate failure to provide supervision where it was obviously called for. It is a tribute both to school teachers and the insurance companies issuing these policies that up to the present there have been few, if any, cases in which a company has sought to rely on a safeguarding clause.

#### THE POISON ACTS

The Poison Acts do not seem to have any bearing on the use of chemicals in a laboratory. It has been accepted in the courts that the pupil's access to dangerous chemicals is a necessary part of the work to be done in a school and that if reasonable care is exercised in storing the stock, no action lies on this account. It has been accepted, too, that sixth-form pupils at least may be allowed reasonable access to stock.

## DUTY-FREE METHYLATED SPIRIT

The supply of duty-free spirit also comes under the heading of this chapter. There are two kinds of duty-free spirit. One is industrial methylated spirits containing 95 per cent. ethyl alcohol plus water and 5 per cent. wood naphtha. It is colourless and gives a clear solution in water. It is suitable for practically all purposes for which alcohol is needed in a school laboratory. The other is duty-free spirit which contains only ethyl alcohol and water.

The former spirit can be obtained by a school without difficulty. Application must be made to the Custom House, London, E.C.3. It must be stated whether it is intended to purify the spirit or not. If a still is to be used permission must be obtained. An undertaking must be given that the spirit will be kept under lock and key in control of a master and that the spirit will not be used for any purpose other than that of science teaching. A return of the amount used each year for teaching purposes will be asked for. An application for the supply of duty-free spirit must be made only for specified particular purposes, and it will only be granted if it is proved that methylated spirits are unsuitable or detrimental to the work proposed.

The full regulations for the supply of duty-free spirit can be obtained from the local excise officer or from the Secretary, Custom House, and any difficulty should be reported to the Science Masters' Association.

It should be realised that the use of a still for alcohol requires a licence whether permission to obtain duty-free spirit has been applied for or not.

## EXPERIMENTS WITH ANIMALS

Such experiments as are calculated to cause pain to living vertebrate animals are prohibited, unless they are performed under the conditions laid down in the Cruelty to Animals Act, 1876.

To comply, an experiment illustrating a lecture should be certified by a professor of a medical faculty in the United Kingdom as being absolutely necessary for the due instruction of pupils in physiological knowledge, and be performed in a registered place.

The certificate will be lodged with the Secretary of State, who can disallow it, at least a week before the performance of the experiment. During the experiment the animal must be under an effective anæsthetic. The animal, if it has suffered serious injury, must not be allowed to recover before being killed.

## APPENDIX I

### FACILITIES FOR FURTHER INSTRUCTION IN SCIENCE

Two types of boy will need advice on how to obtain further instruction in Science : those who leave school after obtaining a Higher School Certificate, and those who have only a School Certificate. The former will tend to continue instruction in pure Science and a university course will frequently be their aim. Yet they must be advised to plan ahead and decide to what purpose their advanced knowledge will be put after graduating. They will need to be put in touch with a professional body for information as to prospects of, and qualifications needed for, their chosen profession. They will also need guidance as to the assistance to be obtained either through scholarships or from a local education authority. Those who have only the School Certificate will, if scientifically minded, tend to go into industry, and will need to be warned of the limited prospects which are available to one without professional qualifications, and to be told of the part-time instruction available and the certificates or diplomas to be obtained.

It would be impossible in the space available in this book to give a detailed guide to all scientific professions, and to the courses and scholarships available. It must therefore suffice if sources of information are indicated. These will be found to give, in convenient form, particulars of universities, technical colleges, and professional bodies.

An inexpensive book of reference can first be recommended, *Higher Education in Great Britain and Ireland*, Universities Bureau of the British Empire, c/o University College, Gower Street, London, W.C.1. 1s. 6d. Post free 1s. 8d.

This book, primarily designed as a guide for overseas students, gives details of all university courses and some courses at technical colleges. The information is arranged alphabetically under subjects of study.

Two more expensive books cover the field completely :—

- (1) *The Universities Year Book* (Bell, 15s.).
- (2) *Pitman's Handbook of Commercial and Technical Education* (Pitman, 15s., published 1939).

The latter not only gives details of all careers where technical education is essential, but also gives information as to opportunities in

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government and municipal departments, all professional bodies and their examinations, technical institutions (whether day or evening courses), and the diplomas or certificates, other than degrees, which can be obtained as evidence of successful study in any branch of technology.

The following is intended to serve as a guide to those desiring further information.

### SCHOLARSHIPS AND FINANCIAL ASSISTANCE

Enquiries should be addressed to :—

- (a) The Director of Education of the Local Education Authority.
- (b) The Registrars of Universities, or for Oxford and Cambridge, the Tutors of the Colleges.
- (c) The Ministry of Education, Belgrave Square, London, S.W.1, in regard to scholarships in Science and Engineering.
- (d) The Charities Digest and Register (annual publication).

### PUBLIC APPOINTMENTS

#### (a) *The Civil Service*

The Civil Service Commission, or *Civil Service Examinations* (H.M.S.O., 1s. 3d.).

#### (b) *Government Departments*

Admiralty, Whitehall, London, S.W.1. (Engineering and Surveying.)

Ministry of Agriculture and Fisheries, 55, Whitehall, London, S.W.1. (Biology, Agriculture, etc.)

Air Ministry, Kingsway, London, W.C.2. (Engineering and Surveying.)

Colonial Office, Downing Street, London, S.W.1. (Biology, Medicine, and Veterinary Science.)

India Office, Whitehall, S.W.1. (Forestry.)

Post Office—General Post Office, London, E.C.1. (Electrical Engineering.)

Ministry of Transport, Berkeley Square, London, W.1. (Civil Engineering.)

#### (c) *Local Government*

National Association of Local Government Officers, 24, Abingdon Street, Westminster, S.W.1.

Institution of Municipal and County Engineers, 84, Eccleston Square, London, S.W.1.

*(d) Teaching*

The Director of Education of the Local Education Authority.  
The Incorporated Association of Assistant Masters, 29, Gordon Square, London, W.C.1.

The Joint Scholastic Agency, 29, Gordon Square, London, W.C.1.

The Ministry of Education, Belgrave Square, London, S.W.1.

## UNIVERSITY DEGREES

Degrees or diplomas of professional bodies, the examinations for which are in many cases of the same standard as University Finals, are essential to the practice of, or the gaining of responsible positions in many professions, such as Medicine, Dentistry, Veterinary Surgery, Engineering (Civil, Mechanical, Electrical, Mining, Marine, Chemical) Chemistry (Industrial, Analytical, Metallurgical), Physics (Industrial and Research), Architecture, and Teaching.

It should be borne in mind that there now exist many degrees other than B.A., B.Sc., B.Sc. Eng., M.B., B.S., such as B.Sc. Industrial Fermentation (Birmingham), B.Arch. (Liverpool), B.Pharm. and B.Sc. Hort. (London), B.Sc. Tech. (Manchester), B.Sc. Forestry (Edinburgh), etc.

Information of all these can be obtained from the *Universities Year Book* and *Higher Education in Great Britain and Ireland*.

## CERTIFICATES AND DIPLOMAS IN TECHNOLOGY

Full-time students can obtain National Diplomas and part-time students National Certificates. Examinations for these are conducted by professional institutes and awards are made by joint committees of the institutes and the Ministry of Education. The National Certificates are the qualifications mostly sought after by the student who has not the ability or the time to work for a degree in his spare time. They are awarded in Building, Chemistry, Electrical Engineering, Mechanical Engineering, Naval Architecture, and Textiles.

In addition, professional bodies conduct their own examinations, leading to such qualifications as "Associate of the Royal Institute of Chemistry," A.R.I.C.; "Associate Member of the Institute of Mechanical Engineers," A.M.I.Mech.E., etc.

As a result of more advanced study or research, higher qualifications may be obtained, such as the Fellowship of the Institute of Chemistry.

Qualifications can also be obtained by taking the examinations of several bodies whose examinations are not confined to any one branch of technology or engineering. These are :—

The City and Guilds of London Institute, Gresham College, Basinghall Street, London, E.C.2.

(Enquiries to the Superintendent, Department of Technology, City and Guilds of London Institute, 31, Brechin Place, London, S.W.7.)

Union of Lancashire and Cheshire Institutes, 33, Blackfriars Street, Manchester, 3.

East Midland Educational Union, University College Buildings, 22, Shakespeare Street, Nottingham.

Northern Counties Technical Examinations Council, 1, Claremont Place, Newcastle-on-Tyne, 1.

Union of Educational Institutions, 89, Cornwall Street, Birmingham, 3.

West Riding County Council Technical Examinations Board, Education Department, County Hall, Wakefield, Yorks.

These examining bodies work in co-operation with most technical colleges where suitable courses of study are provided.

### SUBJECTS OF STUDY

Pure Science (Chemistry, Physics, Botany, Zoology, Geology) can be studied at all universities and at all the larger technical colleges, and Engineering (Civil, Mechanical, Electrical) at all technical colleges and all universities (except Reading). Courses in Medicine and Surgery are provided at all universities (except Reading) for the degrees of M.B. and B.Ch. and the diplomas, M.R.C.S., L.R.C.P., awarded by the Conjoint Board of the College of Physicians and Surgeons, and for degrees in Dentistry at all universities except Cambridge, Oxford, Reading, Wales, and the Scottish Universities. The University of London, by granting external degrees, has enabled students to graduate by private study or by study at the provincial colleges such as the University Colleges at Exeter, Southampton, Nottingham, Hull, and Leicester.

The following is a brief list of the most important institutions providing facilities for the study of specialised subjects. Courses vary considerably at the different universities and technical colleges and enquiries should therefore be made direct when further information is required.\* The professional body given can advise on the prospects of the proposed vocation and give particulars of its own examinations.

### AGRICULTURE (INCLUDING DAIRYING AND HORTICULTURE)

#### *Universities*

Bristol, Cambridge, Durham, Leeds, London, Oxford, Reading, Wales (Aberystwyth, Bangor), Aberdeen, Edinburgh, Glasgow, Belfast.

\* Where a University is mentioned, a degree can usually be taken in the subject, and where a Technical College, the National Certificate.



*Other Institutions*

South-Eastern Agricultural College, Wye, Kent.

Midland Agricultural College, Sutton Bonnington.

Seale Hayne Agricultural College, Newton Abbot, Devon.

Harper Adams Agricultural College, Newport, Salop.

Royal Agricultural College, Cirencester.

Various County Farm Institutes (particulars from the Ministry of Agriculture).

Royal Agricultural Society, 16, Bedford Square, London, W.C.1.

Royal Horticultural Society, Vincent Square, Westminster, S.W.1.

(National Diplomas in Agriculture, Dairying, and Horticulture.)

See also *Agricultural Education in England and Wales* (A.695 TE).

Ministry of Agriculture, 55, Whitehall, London, S.W.1. (Gratis.)

## AERONAUTICS

*Universities*

Cambridge, London, Glasgow, Southampton (University College).

*Other Institutions*

Loughborough Technical College.

Royal Aeronautical Society, 4, Hamilton Place, London, W.1.

## ARCHITECTURE

*Universities*

Cambridge, Durham, Liverpool, London, Manchester, Sheffield, Glasgow.

*Technical Colleges and Institutions*

Aberdeen, Birmingham, Cardiff, Manchester, Edinburgh, London (Architectural Association, School of Architecture, 34-36, Bedford Square, W.C.1.).

Royal Institute of British Architects, 66, Portland Place, London, W.1.

## BACTERIOLOGY

All Universities. Diplomas at London and Manchester Universities.

Many Technical Colleges.

## BIOCHEMISTRY

All Universities.

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### BREWING

#### *Universities*

Birmingham, Manchester.

#### *Technical Colleges and Institutions*

London and Edinburgh.

Institute of Brewing, Brewers' Hall, Addle Street, London, E.C.2.

### BUILDING

#### *Universities*

Manchester, Wales (Cardiff), Belfast.

#### *Technical Colleges and Institutions*

Portsmouth, Widnes, Salford, Norwich, Rugby, Birmingham, Edinburgh, Glasgow, London (L.C.C.).

Institute of Builders, 48, Bedford Square, London, W.C.1.

### CHEMISTRY

All Universities and Technical Colleges.

Royal Institute of Chemistry, 30, Russell Square, London, W.C.1.

### CHEMICAL ENGINEERING AND TECHNOLOGY

#### *Universities*

London, Manchester, Glasgow, Liverpool, Edinburgh, Belfast, Leeds (Leather Industries), Sheffield (Glass Technology).

#### *Technical Colleges and Institutions*

Cardiff, Loughborough, London (Leathersellers' College).

Institution of Chemical Engineers, 56, Victoria Street, London, S.W.1.

### COLOUR CHEMISTRY (DYEING, ETC.)

#### *Universities*

Leeds, Manchester, Glasgow, Belfast, Nottingham University College.

#### *Technical Colleges*

Bradford, Galashiels, Leicester.

### DENTISTRY AND MEDICINE

Courses at all Universities (except Reading) leading to a degree, and at Medical Schools attached to larger London and Provincial Hospitals leading to the diplomas M.R.C.S., L.R.C.P., and for Dentistry the diploma L.D.S., R.C.S.

General Medical Council, 44, Hallam Street, London, W.1.

Dental Board of the United Kingdom, 44, Hallam Street, London, W.1.

## ENGINEERING

All Universities and Technical Colleges.

*Institutions*

Automobile Engineers, 12, Hobart Place, London, S.W.1.

Civil Engineers, Gt. George Street, Westminster, London, S.W.1.

Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

Mechanical Engineers, Storey's Gate, St. James's Park, Westminster, London, S.W.1.

Municipal and County Engineers, 84, Eccleston Square, London, S.W.1.

Sanitary Engineers, 118, Victoria Street, London, S.W.1.

Structural Engineers, 11, Upper Belgrave Street, London, S.W.1

Paraday House, 62, Southampton Row, London, W.C.1.

## FORESTRY

*Universities*

Bristol, Wales (Bangor), Aberdeen, Edinburgh.

Ministry of Agriculture, 55, Whitehall, London, W.1.

## MARINE BIOLOGY AND OCEANOGRAPHY

*Universities*

Liverpool, Wales (Aberystwyth). Courses also at Aberdeen, Durham, and Wales (Bangor), and University College, Hull.

## MARINE ENGINEERING

*Universities*

Durham, Liverpool, Aberdeen, Glasgow, Belfast, Southampton University College.

*Technical Colleges and Institutions*

Cardiff, Sunderland, and Portsmouth.

Institute of Marine Engineers, 85, Minories, London, E.C.3.

## METALLURGY

*Universities*

Birmingham, Bristol, Cambridge, Durham, Leeds, Liverpool, London, Manchester, Sheffield, Wales (Cardiff and Swansea), Edinburgh, Glasgow.

*Technical Colleges and Institutions*

Birmingham, Bradford, Leicester.

Institution of Mining and Metallurgy, 438A, Salisbury House, London, E.C.2.

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### MINING

#### *Universities*

Birmingham, Durham, Leeds, London, Manchester, Sheffield, Wales (Cardiff), Edinburgh, Glasgow, Nottingham University College.

#### *Technical Colleges and Institutions*

Stoke-on-Trent, Wigan, Cornwall (Camborne School of Metalliferous Mining).

Institution of Mining Engineers, 436, Salisbury House, London, E.C.2.

### OPHTHALMIC OPTICS

All Universities—part of Medical Course.

British Optical Association, 65, Brook Street, London, W.1.

### PHARMACY

#### *Universities*

London, Manchester, Wales, Glasgow, Belfast, Nottingham University College.

#### *Technical Colleges and Institutions*

Aberdeen, Birmingham, Bradford, Edinburgh, Leicester, Liverpool, Salford, Salford, Sunderland, Portsmouth, London (Chelsea), Norwich, Birmingham, Coventry.

Many others provide short courses.

Pharmaceutical Society of Great Britain, 17, Bloomsbury Square, London, W.C.1.

### PETROLEUM TECHNOLOGY

#### *Universities*

Birmingham and London.

Institute of Petroleum, 26, Portland Place, London, W.1.

### PHYSICS

All Universities and Technical Colleges.

Institute of Physics, 19, Albemarle Street, London, W.1.

### TEXTILES

#### *Universities*

Leeds, Manchester, Glasgow, Nottingham University College.

#### *Technical Colleges and Institutions*

Bradford, Dundee, Galashiels, Leicester, Stockport, Derby, Blackburn, Bolton, Burnley, Salford, Keighley, Huddersfield, Halifax.

Textile Institute, 16, St. Mary's Parsonage, Manchester, 3.

## VETERINARY SCIENCE

*Universities*

Liverpool, London (Royal Veterinary College), Manchester, Edinburgh.

Royal College of Veterinary Surgeons, 10, Red Lion Square, London, W.C.1.

## PROFESSIONAL EXAMINING BODIES NOT INCLUDED IN THE ABOVE

Chartered Surveyors' Institution, 12, Gt. George Street, Westminster, S.W.1.

National Association of the Boot and Shoe Industry, 7, Tavistock Square, W.C.1.

Institution of the Rubber Industry, 12, Whitehall, London, S.W.1.

Institution of Gas Engineers, 1, Grosvenor Place, London, S.W.1.

The Royal Sanitary Institute, 90, Buckingham Palace Road, S.W.1.

Chartered Institute of Patent Agents, Staple Inn Buildings, London, W.C.1.

Incorporated Association of Architects and Surveyors, 75, Eaton Place, London, S.W.1.

The Institute of Wireless Technology, 25, Firs Drive, London, N.13.

## MISCELLANEOUS ADDRESSES

Department of Scientific and Industrial Research, 24, Rutland Gate, London, S.W.7., and 16, Old Queen Street, London, S.W.1.

Miners' Welfare Commission (Scholarships), Ashley Court, Ashtead, Surrey.

The Chief Education Officer, County Hall, London, S.E.1. (Facilities for the study of practically all subjects are provided by the London County Council and are made available to those living in most neighbouring counties on payment of special out-county fees, by arrangement with their local education authorities.)

## APPENDIX II

### EXAMPLES OF NEW-TYPE TESTS

#### 1. COMPLETION TEST

Fill in the blanks :—

- (a) The chemical name for laughing gas is .
- (b) The chemical name for  $\text{HNO}_3$  is .
- (c) Zinc + dilute sulphuric acid : : + .
- (d)  $2\text{NaCl} + \text{Pb}(\text{NO}_3)_2 =$  + .
- (e) The formula  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  indicates that 249.5 gm. of crystals of copper sulphate contain gm. of water.
- (f) Water has its maximum density at degrees centigrade.
- (g) The gaseous law expressed by the formula  $p \propto \frac{1}{v}$  constant, was discovered by in the century.
- (h) 26 c.c. of hydrogen, when completely burned in oxygen, will give c.c. of steam at the same temperature.
- (i) Temporary hardness in water is due to the presence in solution of .

Completion tests can also be set in the form of a complete passage, in which important words have been omitted.

#### *Advantages*

Completion tests discourage note-learning and encourage concentration on details, brevity, and conciseness. They are quickly answered, easily scored, and many different ones can be set (adequate sampling).

#### *Disadvantages*

It is difficult to set good ones (testing understanding). Also it is difficult to set them so as to weight different items in the syllabus according to their intrinsic value.

#### 2. MULTIPLE CHOICE TEST

Underline the correct answer :—

- (a) The velocity of light, in miles per second, is :—  
(1) 20 ; (2) 860 ; (3) 186,000 ; (4) 300,000.
- (b) Oxygen was first prepared by :  
(1) Priestley ; (2) Boyle ; (3) Cavendish ; (4) Avogadro ;  
(5) Dalton.

- (c) As water when heated changes to steam, its volume :—  
 (1) increases ; (2) decreases ; (3) remains the same ; (4) vanishes ; (5) condenses.
- (d) The least soluble salt among the following is :—  
 (1) copper sulphate ; (2) sodium chloride ; (3) ferrous sulphate ; (4) barium sulphate ; (5) calcium chloride.

The score for a series of such questions (five choices) would be equal to Right minus Wrong.

The pupil is helped, but he would be helped in any practical situation. In any case, we can recognise the meaning of more words than we can use in sentences of our own construction. The test gives a measure of the pupil's "acquaintance with" phases of the subject matter, while the completion form tests "knowledge about."

### 3. TRUE-FALSE TEST

Mark true (T) or false (F) in the brackets :—

- (a) The equivalent weight of an element is the weight of hydrogen which 1 g. of the element will give, combine with, or replace. ( )
- (b) Solubility is increased by stirring. ( )
- (c) Carbon dioxide contains its own volume of oxygen. ( )
- (d) All carbonates give carbon dioxide on heating. ( )
- (e) A basic oxide is the oxide of a metal. ( )
- (f) A metal is an element whose oxide is basic. ( )
- (g) The speed of light in water is greater than in air. ( )
- (h) The atomic weight in grams of all elements contains the same number of atoms. ( )
- (i) All atoms have the same capacity for heat. ( )
- (j) The acid carbonate of sodium is alkaline to litmus. ( )
- (k) When an electric current is passed through a solution of an electrolyte, it divides the molecules of the solute into charged particles called "ions." ( )

Score = Right minus Wrong.

It should be noted that to answer these questions correctly demands the application of known facts and principles to new situations. They are not nearly so simple as they seem. They are easily marked by the aid of a stencil, and as many as 150 may be given in a one-hour examination.

### 4. SENTENCE DISCRIMINATION

Underline one alternative in each case so as to make the best sense :—

- |     |                                |                                  |
|-----|--------------------------------|----------------------------------|
|     | coal                           | sulphuric acid                   |
| (a) | When sulphur is burned in air, | carbon dioxide      is produced. |
|     | magnesium                      | magnesium sulphate               |

- (b) One way to prepare hydrogen is to add carbon  
copper  
zinc  
nitric acid  
to dilute sulphuric acid  
sodium carbonate
- (c) The volume of a given mass of gas at constant temperature is  
pressure  
density  
weight  
inversely proportional to its pressure  
density

## 5. LOGICAL SELECTION

Cross out the word or formula or symbol which does not belong to the line :—

- (a) Copper : iron : carbon : zinc : magnesium.  
(b) Hydrogen : calcium : oxygen : chlorine : nitrogen.  
(c) Carbon : coke : soot : coal : graphite.  
(d) Na : K : Ca : Rb : Cs.  
(e) Lead nitrate : sodium nitrate : copper nitrate : potassium nitrate : ammonium nitrate.  
(f) PbS : ZnS : HgS : CuS : CdS.  
(g) Potassium chlorate : potassium nitrate : hydrogen : manganese dioxide : oxygen.  
(h) Phosphoric oxide : copper oxide : iron oxide : lead oxide : zinc oxide

Probably a better rubric would be : " In each of the following groups, *one* substance has some *one* important property which distinguishes it from the remainder ; underline the name of this substance."

## 6. REASONING TEST

Underline the *best* answer :—

- (a) A solid weighs less in water than in air because  
(1) The solid is heavier than the same bulk of water,  
(2) The loss of weight of the solid is equal to the weight of water displaced,  
(3) The water exerts an upward thrust on the solid,  
(4) The vessel in which the solid is weighed bears some of the weight.
- (b) Water, on being heated, changes to steam because  
(1) The vapour pressure increases with rise of temperature.  
(2) The temperature of the steam is higher than that of boiling water,



- (3) The energy of the water molecules becomes so great that the molecules are projected beyond the surface of the water,
  - (4) Steam has latent heat.
- (c) Air is a mixture because
- (1) It is not soluble in water,
  - (2) It is invisible,
  - (3) Its composition varies,
  - (4) It has no effect on litmus.

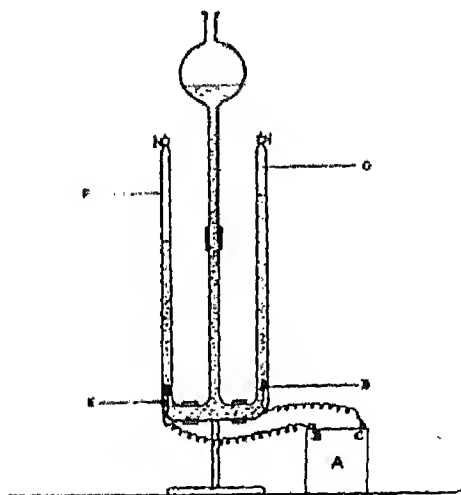


Figure 32

- (d) Glass is a mixture because
- (1) It is transparent,
  - (2) It is brittle and easily breaks,
  - (3) It is not acted upon by acids,
  - (4) It melts gradually.
- (e) Iron is an element because
- (1) It gives hydrogen with dilute sulphuric acid,
  - (2) It is magnetic,
  - (3) No one has yet split it up,
  - (4) It rusts in air.

## 7. MATCHING TEST

(i) Put in front of the letters of column two, the correct numbers from column one.

(1) $\text{NaCl}$	(a) Limestone
(2) $\text{N}_2\text{O}$	(b) Blue Vitriol
(3) $\text{KNO}_3$	(c) Slaked Lime
(4) $\text{CuSO}_4$	(d) Laughing Gas
(5) $\text{CaCO}_3$	(e) Saltpetre
(6) $\text{Ca(OH)}_2$	(f) Common Salt

These again test "acquaintance with." Such a test is not desirable unless there are at least fifteen items in each list.

## 8. IDENTIFICATION TEST

(a) Identify the parts A, B, C, D, E, F, and G of the apparatus shown in the accompanying diagram. (Fig. 32.)

(b) Mark the direction of the current in the coiled wires.

## APPENDIX III

### NOTES ON SPECIFICATIONS

The notes which follow give an indication of the type of document commonly used with specifications.

#### GENERAL

Firms are invited to tender for the items described. A key plan has also to be provided. Full details and drawings or illustrations of all fittings must be furnished. Tenderers should indicate clearly any alternatives suggested by them.

Tenders must include, and will be accepted only as including, everything necessary to make the whole of the fittings provided replete with all connections and appropriate details perfect, complete, and in every way ready for use.

All fittings should be fixed in positions shown, neatly scribed to walls and floors and any adjacent work. The various fittings should be carried out in accordance with the drawings, with this specification, and with the additional particulars furnished by the firm tendering. Everything must be completed to the satisfaction of the Education Authority's Architect. Any inferior material or workmanship must be rejected and replaced by other approved material.

Tenders should include the maintenance of all work in a satisfactory state for a period of 12 months after completion.

Allowance must be made in the plan for all fixed heating, pipes and radiators, piers, etc., as these cannot be modified and firms tendering will be responsible for all measurements of fittings and placing.

The tenders must clearly define the limits of all services and wastes and state precisely the materials of which the various portions of the work will be made.

Jointing and fitting generally must include first-class joiners' work with tenons properly wedged, glued, and finished. All benches against walls should be fitted with skirtings 3 in. high.

#### MATERIALS

The quality of teak should be specified, e.g., Moulmein. No plywood should be used for shelves. Exposed timber : pitch pine should be used, red deal where hidden from view. All timber should be

free from any defect whatsoever, of first quality, well seasoned, and finished true and clean.

Bench tops must be properly wax-polished or oil-treated. The edges around sinks must be throated.

All the pitch pine work should be sized and twice varnished with best hard Church oak varnish supplied by a firm approved by the architects.

### CUPBOARDS AND DRAWERS

Drawers should have hardwood runners and  $\frac{1}{2}$  in. fronts with  $\frac{1}{2}$  in. backs and sides all dove-tailed, grooved, glued, and blocked.

Cupboard fronts should have a minimum of  $\frac{3}{4}$  in. thickness framing with  $\frac{1}{2}$  in. full panels. All panels should be prepared and varnished before fixing into framing.

Interiors of glazed cupboards must be as specified (e.g., British Columbian pine), and these and the insides of all doors should be sized and varnished in the same way as the outside.

Backs of cupboards against walls should have a coat of Solignum or Presotim preservative, while the inside of the back should be painted white.

2-lever brass locks should be fitted on drawers and cupboards where stated. Except in a senior chemistry laboratory all locks in a room should be alike, but those in each room should differ, with a master key to cover all suites. Four master keys should be provided. Locks should be to sample submitted to and approved by the Education Authority's Architect.

All other necessary ironmongery should be appropriate and in accordance with approved samples.

Drawer pulls should be of non-corrodible metal or hardwood. On all drawers and cupboards there should be a slot of non-corrodible metal suitable for contents card.

All drawers should be fitted with a simple device to prevent their being pulled right out inadvertently.

In every drawer an unfixed division strip of hardwood to fix the longest way of the drawer should be provided.

Glass panels should be of 26 oz. British sheet clear glass, free from any defect and fixed with beads and washleather.

### PIPES, TAPS, SINKS

Water taps should be of gun-metal or stainless steel, of British make and anti-splash design, and prepared to receive rubber tubing. They should be stamped approved by the local waterworks department.

Gas fittings should be of British make and of gunmetal of extra heavy design.

All these fittings should be of uniform finish throughout, samples being submitted to and approved by the senior science master.

All lead waste pipes should be British made, cold drawn, and of weights as follows :—

1 inch . . . . .	7 lb. per lineal yard
1½ „ . . . . .	9 lb. „ „ „
1¾ „ . . . . .	11 lb. „ „ „
2 „ . . . . .	14 lb. „ „ „

All waste pipes should be coated internally with bitumen. Floor channels will be provided by the general contractor.

Sinks should be best quality heavy white, glazed inside and outside fireclay, having removable grids (lead, fireclay, vulcanite), in the outlets and removable vulcanite standing overflow plug fitted. Samples of fittings should be approved.

Where fume pipes are required, nozzles need to be provided on the outside of the fittings from which the general contractor can run pipes to fan chambers.

Water and gas supply pipes will be laid to one point in each room and the tenders must include the provision and fixing of all water and gas pipes from these points to all taps, etc., on benches or walls, with all joints and connections.

## APPENDIX IV

*Administrative Memorandum No. 167.*  
(5th July 1937)

### BOARD OF EDUCATION

#### *Experiments on Explosives in Schools*

An explosion recently occurred during a science lesson in a senior school whereby the master received serious injuries.

The experiment in progress was the making of a bomb to be exploded in the playground. Powdered chlorate of potash and antimony sulphide had been mixed in an envelope; red amorphous phosphorus was then added, the explosion occurring when the contents of the envelope were stirred with a piece of school chalk.

This followed a series of experiments on matches and explosives taken from a textbook on Science, the issue of which has since been suspended by the publishers as a result of representations made by the Home Office. Among the suggestions for experiments on explosives made in this book were :—

- (i) the making of gunpowder in small quantities for experimental purposes; this, while not illegal, is strongly deprecated by the Home Office;
- (ii) mixing phosphorus and chlorate of potash;
- (iii) mixing chlorate of potash and sulphur.

Both of these have been made illegal by Order in Council on account of the extremely sensitive and violently explosive character of these mixtures.

The Home Office has drawn the Board's attention to the fact that chemical sets for children frequently include chlorate of potash, sulphur, and phosphorus, and that children's magazines often contained detailed instructions for the making of fireworks, an unlawful act. The Home Office also states that, contrary to the usual belief, red phosphorus need not be contaminated with yellow for it to explode when mixed with chlorate of potash.

The part that Chemistry should play in senior school science is indicated in the recently issued *Handbook of Suggestions*; in secondary schools the adoption of General Science implies a similar rule for Chemistry, ancillary to the study of Biology and Physics. The study

of explosives is quite unsuitable in all types of schools, for pupils below the stage of the School Certificate Examination.

Local Education Authorities and School Governors are asked to bring the facts, outlined above, especially those relating to the illegality of making explosives, to the early notice of headmasters and mistresses and of science teachers of all schools provided or maintained by them in which Chemistry is taught.

It is also suggested that attention should be drawn to the possible dangers of chemical sets and articles about fireworks in children's magazines.

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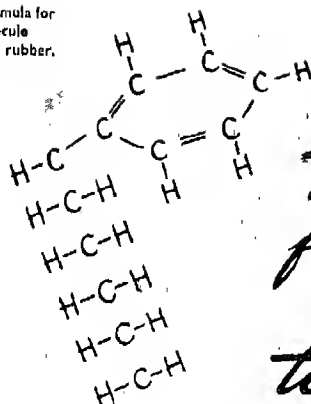
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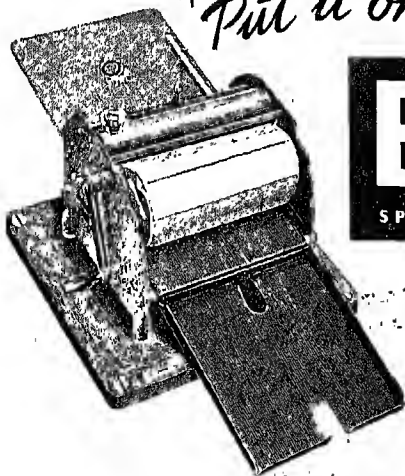


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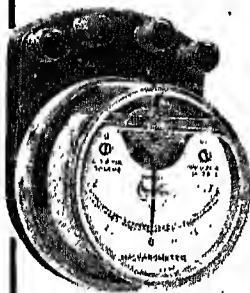
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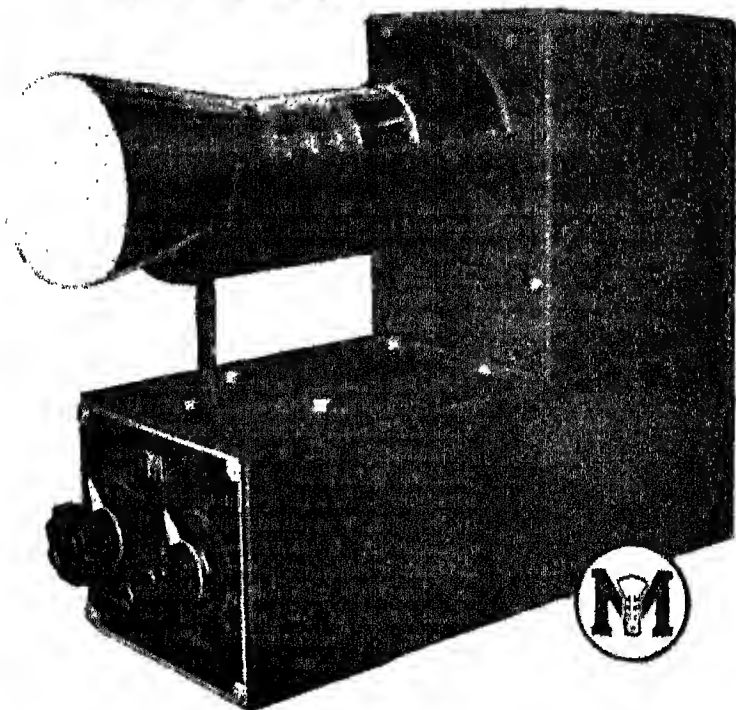
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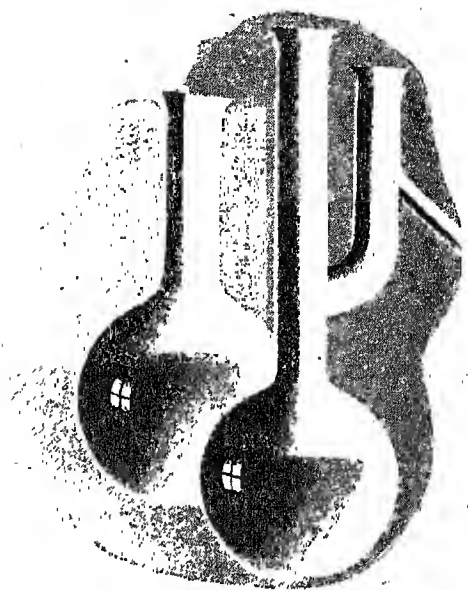
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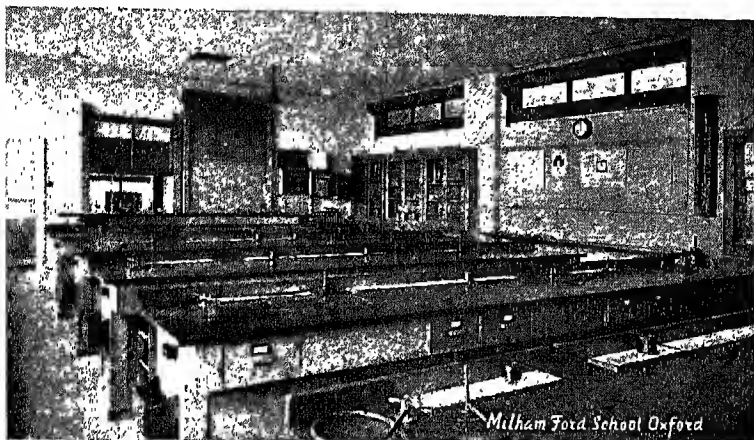
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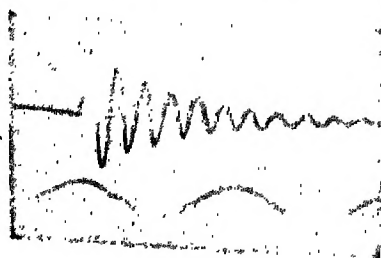
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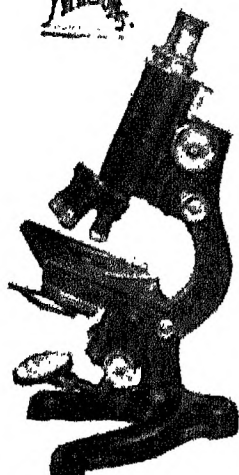


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